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THE ECONOMIC DIMENSIONS OF CONDENSERS AND COOLING PLANTS.

By DR.-ING. ALBERT FONÓ.

WHEN designing a power plant, it is necessary to estimate for the amortisation, in addition to satisfying the other requirements. If the amortisation is determined beforehand, the rating and price of the plant can be fixed at an appropriate relationship to its economy. This relationship can be regarded as satisfied when the annual amortisation, at the given rate of interest on the amount of capital invested during the given time, is equal to the annual saving. If the amount of capital invested is to be kept low, the amortisation time will be a minimum, but if future savings are considered to be of greater importance than capital expenditure, the amortisation time will exceed the minimum correspondingly. To find the correct solution of the problem, the variation in load expected during the year must be known, as well as the variation in the conditions which influence the economy of the plant.

The author deals below with the rating of the condenser equipment of a steam turbo-generator set, and with the associated water-cooling plant. Usually, condensing equipment is rated and supplied with the steam turbine, while the water-cooling plant is generally supplied by a different manufacturer. Since the dimensions of the condenser and the cooling plant are closely related, it is important to consider their respective ratings together. The main dimensions of a condensing plant are the surface of the condenser and the capacity of the circulating pump, the latter being fixed by the quantity of circulating water. The main dimension of a water-cooling plant of given type is the area of the base on which the drops of water fall.* For the condenser, the conditions influencing the rating are the quantity and the heat content of the steam to be condensed per hour, and the inlet temperature of the cooling water. For a given cooling plant using a given quantity of circulating water, this inlet temperature depends on the air conditions, namely, the temperature, relative humidity, wind velocity, and pressure; it also depends on the quantity of heat to be extracted from the circulating water, which, in turn, fixes the temperature drop occurring in the water. The type of plant considered is shown diagrammatically in Fig. 1. Wet steam having a temperature t_2 is condensed in a surface condenser. The heat is removed by the cooling water, circulated by a pump. The temperature of the cooling water, which has been increased from t_1 to t_2, will be reduced in the cooling plant to t_1. To determine the rating, we must know the quantity and heat content of the steam, from the average to the peak-load conditions; and the air temperature, relative humidity, velocity, and pressure from the average to the most unfavourable conditions.

Load on the Condenser.—The load on the condenser, namely, the quantity and heat content of the steam entering it, depends on the steam-turbine load and on the efficiency of the turbine at that load. The efficiency depends on the inlet temperature of the cooling water, which, in turn, is a function of the cooling equipment and of the air conditions. The steam-turbine load is, however, independent of air conditions. The variations of these two independent variables must first be investigated. To obtain the law of the turbine-load variation, data are either obtained from an existing plant, or are calculated from the proposed working conditions in the case of a new plant. From the hourly data the frequency curve, Fig. 2, is drawn, using as ordinates the number of hours per year during which the load in kilowatts does not exceed the values plotted as abscissæ. The number of working hours h, per year, corresponds to the ordinate at the right-hand side. The "surface-levelling" ordinate N_a gives the probable average annual load of the plant. To find the probable "frequency" of steam consumption, *i.e.*, the frequency of a particular load on the condenser, the air conditions and their influence on water cooling must be investigated.

Influence of the Air.—Apart from variations in the load on the turbine, variations occur in the air conditions. These comprise air temperature and relative humidity which together determine the heat content of the air, the wind velocity, and the barometric pressure. The advantage of using the single quantity, heat content of the air, instead of the more usual data involving temperature and relative humidity, is that it facilitates subsequent calculations. The wind velocity fluctuates independently of other air conditions, the annual average velocity being generally below 6 m. (20 ft.) per second. Velocities below this figure can, however, be neglected; consequently, the influence of the wind velocity on the average annual steam consumption of the turbine is negligible. For similar reasons, the influence of the barometric pressure can be neglected. The hourly variation in the heat content of the air, taken over the year, which is characteristic of the given geographical site, can be estimated from the variation in temperature and probable relative humidity. The two latter quantities should be based on meteorological observations taken over many years.

The average relative humidity of the air being known for every place and temperature concerned, the heat content of the air can be calculated and the curve, Fig. 3, giving the probable frequency of the heat contents, can be drawn. The ordinates represent the number of hours per year during which the heat content of the air does not exceed the figure of the corresponding abscissæ. The "surface-levelling" ordinate i_a gives the probable average annual heat content of the air for the site. Fig. 3 refers to a mid-Continental site, where periods of hot and cold weather are much more frequent than transition temperatures. Consequently, there are three points of inflexion on the curve instead of the single one usually observed in this country.

Cooling Plant.—For a suitable condensing and cooling plant, it is possible to determine the temperature t, of the recooled water, for every load, at the average heat content of the air. The load on the cooling plant is characterised by the temperature range Δt, which is the temperature difference between the water at inlet and outlet, *i.e.*, $t_2 - t_1$. Fig. 4* shows the variation of the temperature t_1 of the cooled water with the load (expressed by Δt). Each curve in the series corresponds to a different heat content of the air.

Steam Consumption.—The steam consumption of a turbine is generally given by the manufacturers, on the tender, for every load at a chosen inlet temperature t_1 of the cooling water. In addition, the influence of variations in the cooling-water temperatures on steam consumption is usually indicated. Should the manufacturer's estimate of the cooling-water temperature differ from the actual average figure, the steam consumption can be corrected as for another turbine of the same type and load, but rated for another cooling-water temperature, the steam consumption varying inversely with the heat drop between the admission

Fig. 1.

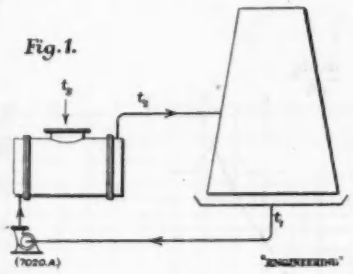


Fig. 2.

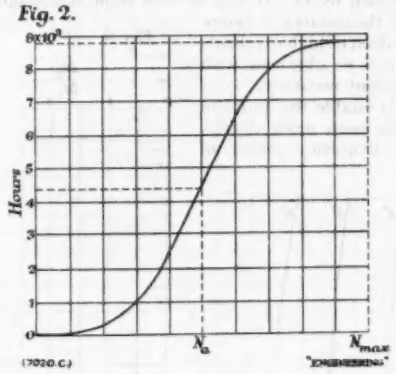


Fig. 3.

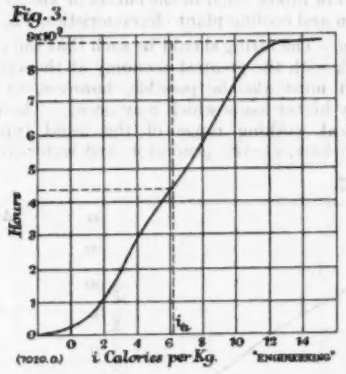


Fig. 4.

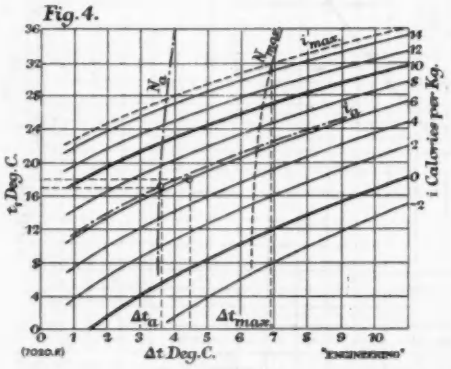


Fig. 5.

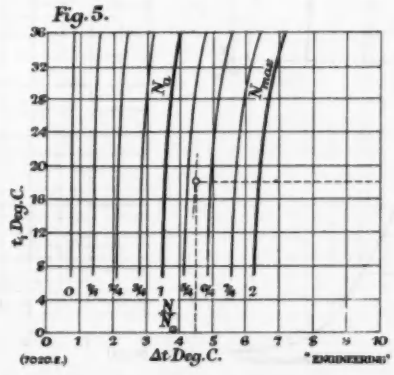
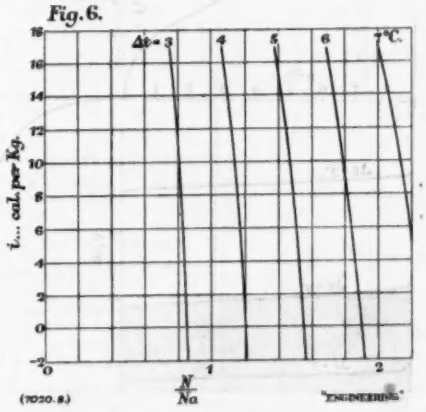


Fig. 6.



* This fact has been dealt with by Merkel, *Z.V.D.I.*, vol. 70, page 123 (1926).

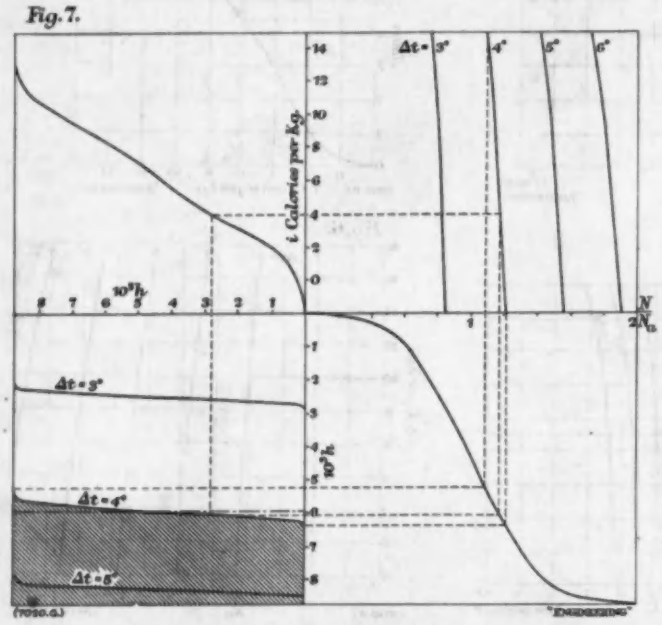
* Deduced from Merkel's diagrammatic treatment of cooling towers. See *Z.V.D.I.*, vol. 70, page 123 (1926,).

and the steam temperature in the condenser. Steam consumption is proportional to the rise Δt in the cooling-water temperature, if the latter is constant in quantity, the small influence of the steam temperature in the condenser on the heat content of the steam being initially neglected. On the foregoing basis, the curves shown in Fig. 5, page 79, can be drawn, giving the relationship between steam consumption (represented by Δt) and cooling-water inlet temperature t_1 for every load N on the generator driven by the turbine, taking the generator efficiency into account at every load.

Having two series of curves giving the relationship between t_1 and Δt for constant values of N and i, the points of intersection supply a relationship between i and N at which Δt is constant. Thus a relationship has been obtained between the load and the heat content of the air, for constant steam consumption (Fig. 6). From the average load N_a (Fig. 2), and the average heat content i_a of the air (Fig. 3), the average steam consumption is found as the point of intersection of the curves of steam consumption and cooling-plant characteristics, Fig. 5.

Rating.—The rating should be such that the plant will work with the greatest economy at the average load. It must also be possible, however, to deal with any higher loads which may occur. The most economical working range of the usual type of steam turbine, electric generator, and water-cooling

Fig. 7.



plant, is generally between three-quarters and the full nominal normal load. Most types of steam turbines can carry an overload of 20-25 per cent. of their normal load, *i.e.*, 20-66 per cent. of the most economical load, which is the average load. In the following treatment, it may be supposed, for example, that an overload of 50 per cent. is permissible. The greatest overload on the turbine, at the highest heat content of the air, leads to the highest overload of steam consumption, which corresponds, in the curves given in Fig. 6, to a load 92 per cent. above the average $\left(i.e., \frac{N}{N_a} = 1{\cdot}92\right)$.

To ascertain what this overload means, we must know the duration, in hours, of the various overload figures, and the probable frequencies of the various steam consumptions must be found.

Frequencies of Various Steam Consumptions.—Fig. 2, page 79, gives the turbine-load frequency, and from Fig. 3 the heat content of the air frequency is known. Moreover, Fig. 6 shows, for constant steam consumptions given by Δt, the relationship between turbine load N and the heat content i of the air. From these quantities the law governing the frequency of the steam consumption can be found by following the method proposed by Kuusinen.*

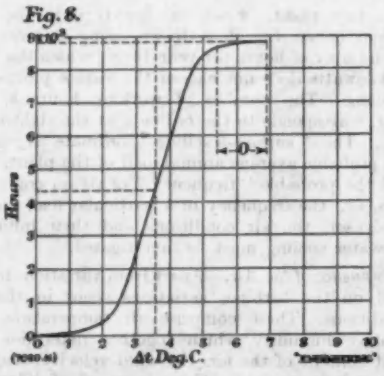
* *Wahrscheinlichkeitsberechnungen in der Kraft- und Wärmetechnik* by Jarl Kuusinen, Åbo Academy, Åbo, Finland.

This is shown in Fig. 7, which consists of a combination of various curves already discussed. The upper right-hand portion corresponds to Fig. 6. To its abscissa axis, Fig. 2 (inverted) is joined below, giving the lower right-hand portion. The upper left-hand portion corresponds to Fig. 3, giving values of h and i, while in the lower left-hand corner a curve for each curve of constant Δt given in Fig. 6 is drawn in such a way that each point corresponds on one side to the frequency of the load N and on the other side to the frequency of the heat content i, of the air. The surface limited by this curve gives the frequency of the particular value of Δt. Repeating this construction for various constant steam consumptions given by Δt, the points on the resulting frequency curve, Fig. 8, are obtained. The average load, which is already known, gives the scale of this diagram.

This frequency curve is determined in order to find the probable duration of the overloads. The overload range between 50 per cent. and 92 per cent. is shown by O. It will be seen from this diagram that the number of hours duration of high overloads cannot be obtained with sufficient accuracy.

To enable the problem to be seen more clearly, the frequency curve of

Fig. 8.

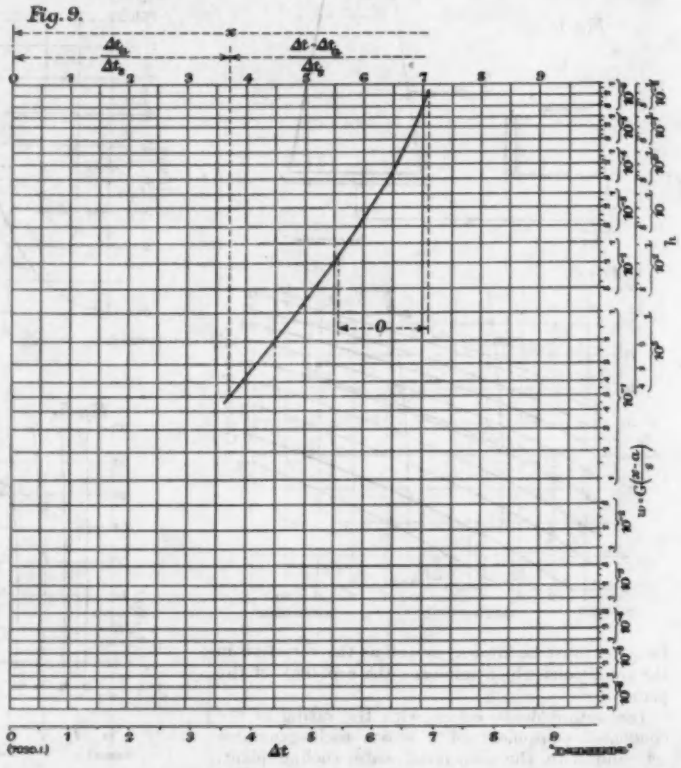


the condenser loads may be redrawn to a Gauss co-ordinate system. Using paper ruled to the Gauss scale, *i.e.*, a scale corresponding to the figures of the Gauss probability equation, a straight line is obtained, showing the probability of occurrences influenced merely by chance in the case of an infinite number of occurrences. In practical cases of limited numbers of occurrences the curves are very flat. The Gauss function $w = G\left(\frac{x-a}{s}\right)$ gives the probability of $\frac{x-a}{s}$, where x is the variant, *i.e.*, the characteristic figure of the occurrence; a is its average and s its square "scatter," so that

$$s^2 = \int_0^1 (x-a)^2 \, dw.$$

The average—corresponding to a frequency of 50 per cent.—is in the middle of the diagram, Fig. 9, and is seen on the line marked 5×10^{-1}, corresponding to $\frac{a}{s}$. The scale of the abscissa of Fig. 9 is consequently $\frac{1}{s}$. In the practical case considered, the variant is the condenser load characterised by Δt. Its average value is $\Delta t_a = 3{\cdot}6$, and its square "scatter" is $\Delta t_s = 0{\cdot}971$. On the abscissa axis is marked $\frac{\Delta t}{0{\cdot}971}$; the yearly working hours are 8,760, and consequently $w = \frac{h}{8{,}760}$.

Fig. 9.



Only the upper half of the frequency curve is reproduced in this system. As the shape of the curve is sufficiently flat, extrapolations can be readily made. The following results can be deduced from this curve:—

Overload, per cent.	50	55	60	70	80	92
Duration of overload, hours	...140	79	42	7·5	0·9	0·014

An analysis of the individual loads may be made to determine whether it is possible to cut off some of the load for a short time, in the case of a high overload. For instance, should it be found possible to cut off 32 per cent. of the average load for 42 hours yearly, then it must still be possible to accommodate up to 10 per cent. of the average load for 98 hours yearly. The method of taking this load will depend on local conditions; it could, for instance, be taken by an older generator of suitable size, if one is available, as the low efficiency of such a generator will not sensibly affect the annual power cost. Should no such arrangement be possible, the capacity of the plant must be increased by 6·6 per cent., in which case the overload of 60 per cent. is reduced to 50 per cent., and this, on the assumptions made, is within the possible overload range for the type of plant chosen. The method shown above thus gives the quantity of steam to be condensed per hour by the condensing equipment at an average load, or at a load which could be regarded as normal.

ECONOMIC DIMENSIONS OF CONDENSERS AND COOLING PLANTS.

Fig. 10.

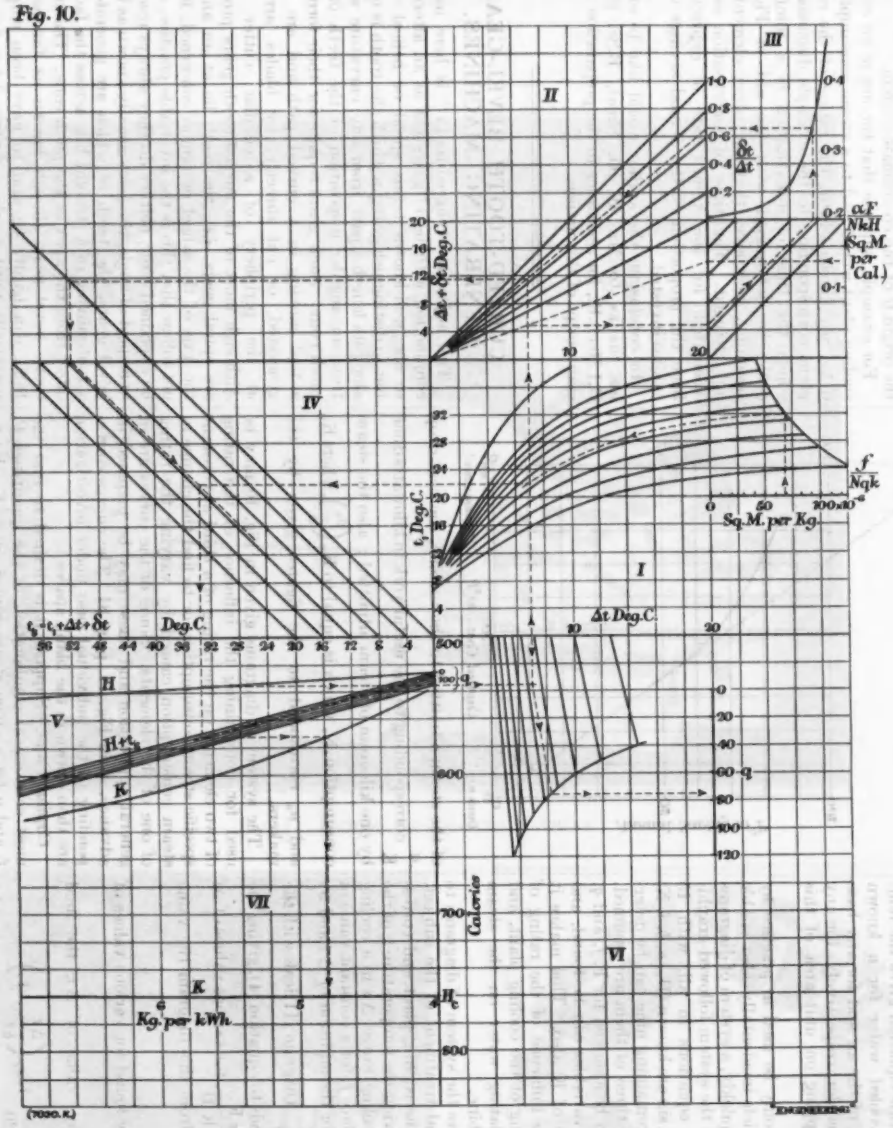
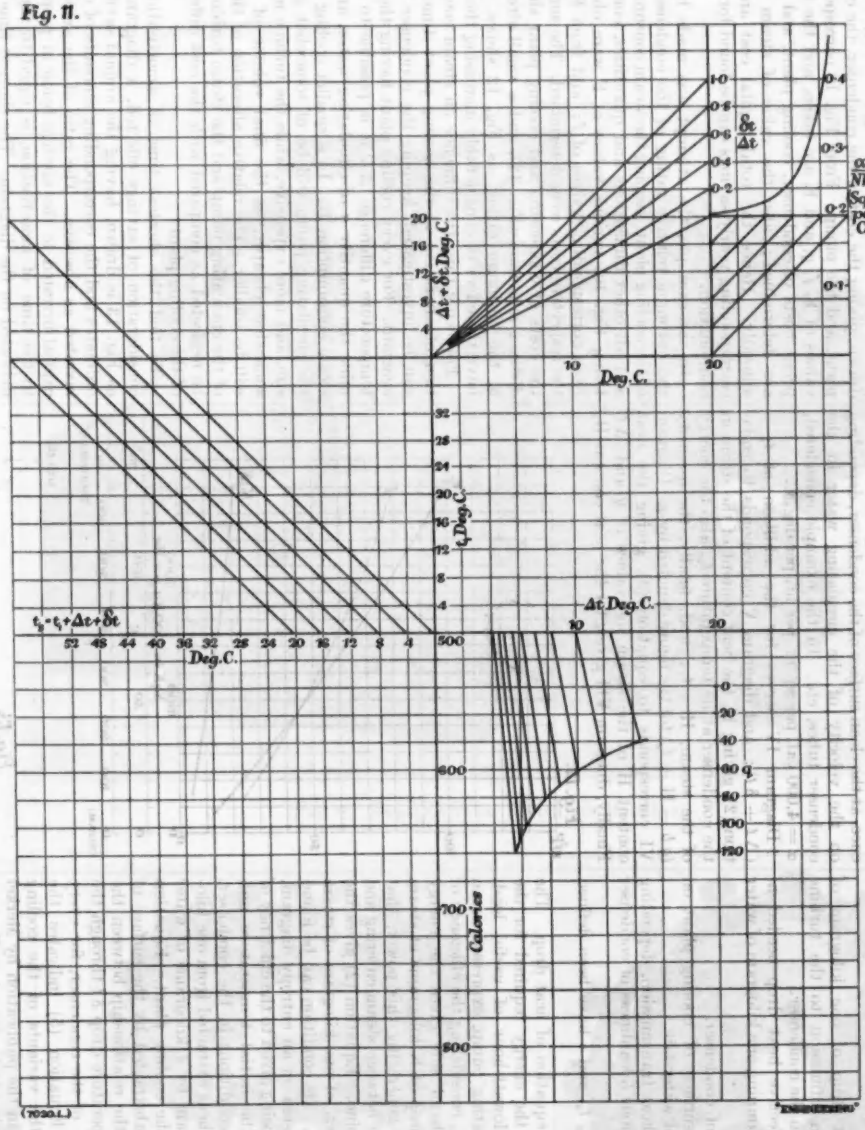


Fig. 11.



The dimensions of the condenser and cooling plant to suit such a load must now be found.

Condenser and Cooling-Plant Dimensions.—For the rating of the condenser and of the cooling plant, the following relations are already known :—

$$K H_c - K(H + t_2) = K a + K b q \quad . \quad . \quad . \quad (1)$$

$$H = \Phi_1(t_2) \quad . \quad . \quad . \quad . \quad (2)$$

$$H = q \Delta t \quad . \quad . \quad . \quad . \quad (3)$$

$$N K H = \alpha F \frac{\Delta t}{\log_e\left(\frac{\Delta t}{\delta t} + 1\right)} \quad . \quad (4)$$

so that

$$\frac{\alpha F}{N K H} = \frac{\log_e\left(\frac{\Delta t}{\delta t} + 1\right)}{\Delta t} \quad . \quad . \quad (4a)$$

$$t_1 = \Phi_2\left(\Delta t\,,\ \frac{f}{N K q}\,,\ i\right) \quad . \quad (5)$$

$$t_2 = t_1 + \Delta t + \delta t \quad . \quad . \quad (6)$$

the value of a being given by the following equation :

$$a = H_c - (H + t_2) - b q.$$

In the above equations, the symbols used are as follows :—

N = Average load on the turbine, in kilowatts, allowing for the load imposed by the auxiliary set, including the circulating pump.

K = Specific steam consumption at this load in kilograms per kilowatt-hour.

H_c = Total energy, in calories, of one kilogram of steam admitted to the turbine.

H = Heat content, in calories, of one kilogram of steam exhausting to the condenser.

q = Quantity of cooling water for one kilogram of condensed steam.

δt = Temperature difference $t_2 - t_1$.

a = Heat requirement in effective heat drop of steam for generating the power of one useful kilowatt-hour, allowing for auxiliary drive.

$\frac{a}{K}$ = Effective heat drop of one kilogram of steam between admission to the turbine and exhaust to the condenser.

b = Energy in effective heat drop needed in practice for pumping one kilogram of water per hour.

F = Surface area of condenser.

f = Ground-level surface of cooling plant on which drops of water fall.

α = Coefficient of heat transmission, depending on the conditions (cleanliness of condenser surface, etc.).

The symbols Δt, t_1, t_2, t_s, and i have been defined earlier.

Equation (1) is the equation of heat drop. The right-hand side gives the energy required for the production of one kilowatt-hour of useful load, allowing for the circulating pump, expressed as an effective heat drop (*i.e.*, considering the efficiency of expansion). The left-hand side gives the energy available in the heat drop of K kilograms of steam which is necessary for generating this power, that is, the energy difference between steam entering and steam leaving the turbine. Equation (2) gives the heat content, in calories, of one kilogram of steam entering the condenser. Its condition can be found by following its expansion on an entropy diagram, due consideration also being given to the efficiency of the expansion from the initial temperature and pressure to the steam conditions in the condenser. Equation (3) gives the heat extracted from one kilogram of condensed steam by q kilograms of water in transporting it to the cooling plant. Equation (4) refers to the heat abstracted by the surface of the condenser, giving the relationship between the surface F and the temperature drop δt through the wall at the hotter end of the condenser, for every load given by Δt. Equation (5) indicates the relationship between the variants of the cooling plant; it is dealt with in the publication by Merkel to which reference has already been made. For any temperature drop, Δt, this equation gives the temperature t_1 of the recooled water for a known average heat content i_a of the air and for any base surface f of the water cooler, respectively, for any intensity of water dropping on unit area of this surface.

As equation (5) can only be used in practice by graphical methods, which incidentally also enable the results to be found quickly, a system of diagrams may now be drawn and the system followed graphically. There are six equations in all, with 15 variables; of the latter, six are known (H_c, a, b, i, N, and α), and six of the remaining nine can be determined if the values for three of them are assumed. For instance, values can be assumed for F, f, and q, and thus all the other variables can be found, and consequently the value of K also. This makes it possible to observe the influence of the rating of the condenser, the rating of the cooling plant, and the quantity of circulating water on the steam consumption of the turbine.

Fig. 10, page 81, shows the system of diagrams to be used in the graphical treatment of the subject. Diagram I deals with the cooling plant and corresponds to equation (5) giving the temperature t_1 of the recooled water for a cooling range Δt in a cooling plant having a base surface f, for a constant value of i_a. Diagram II serves for the addition of Δt and δt for known values of $\frac{\delta t}{\Delta t}$. Diagram III deals with the condenser and corresponds to equation (4), giving the relationship of $\frac{\delta t}{\Delta t}$ to $\frac{\alpha F}{N K H}$, for various values of Δt and F. For instance, from this diagram the value of $\frac{\log_e\left(\frac{\Delta t}{\delta t}+1\right)}{20}$ can be found for various values of $\frac{\delta t}{\Delta t}$, and hence for any value of Δt, the final relationship $\frac{\alpha F}{N K H} = \frac{20}{\Delta t} \cdot \frac{\log_e\left(\frac{\Delta t}{\delta t}+1\right)}{20}$ can be found. The admissible values of α lie between 2,000 calories and 6,000 calories per square metre per hour per degree Centigrade temperature difference, at the clean surface of the condenser, depending on the velocity of the circulating water in the condenser tubes, etc. In the example considered, α = 4,000 cal. per sq. m. per hr. per deg. C.

Diagram IV serves for the addition of $t_1 + (\Delta t + \delta t)$; and diagram V corresponds to equation (2), giving H, the heat content of the steam in the condenser at its temperature t_s, also the energy of the steam, $H + t_s$; and, finally, the quantity $(q\,b + H + t_s)$ for the figure denoted by q. Diagram VI corresponds to equation (3), giving the heat content H of the steam for values of q and Δt. Finally, diagram VII gives, for the heat content H_c of the steam admitted to the turbine, the heat drop $\frac{a}{K}$ corresponding to the useful work in kilowatts done by one kilogram of steam admitted; also the steam consumption K, which is equal to $K_o\left(\frac{a_o}{a}\right)$, where K_o and a_o correspond to the figures given by the makers.

Fig. 12.

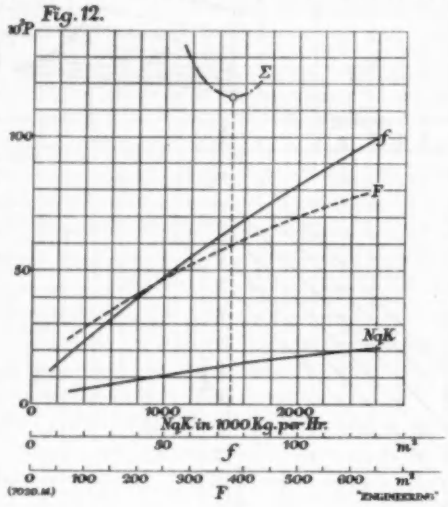
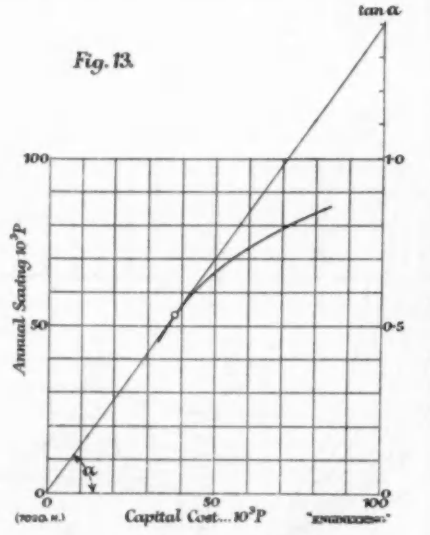


Fig. 13.



The system of diagrams given in Fig. 10 may be used for determining the influence of the rating of two elements on the rating of a third at constant specific steam consumption, or to find the change in steam consumption caused by varying the rating of one of the elements. Some of the curves are of general application and these may be prepared in advance, as in Fig. 11, page 81. The curves corresponding to the individual case under investigation are then drawn in the blank spaces.

Capital Costs.—Suppose it is desired to find the most economical combination of the quantities F, f, and q for a given steam consumption K, also to find the ratings at which the capital cost and the annual saving of steam is either a minimum, or is given. Knowing the cost of steam and the cost of plant for various ratings, diagrams, Fig. 12, are drawn, giving the cost of the condenser, the cooling plant, and the pump. From Fig. 10 corresponding values of F, f, q, and K are taken, and the appropriate costs of condenser, cooling plant, and pump are determined; also the value of steam saved annually. Hence the total capital cost and the corresponding yearly savings can be found for every combination.

In the example, the attempt was made to find the optimum relative rating of the condenser and of the cooling plant, keeping the steam consumption, and all other dimensions and quantities, constant. Using Fig. 10, various values of F were obtained from corresponding values of f; and from Fig. 12 the respective costs were determined. The sum Σ of the costs of condensing and cooling plant shows a distinct minimum (Fig. 12), and a small alteration in the optimum rating, as Fig. 12 shows, would have the effect of considerably increasing the costs.

Following this, the influence on steam consumption of alteration of the cooling plant dimensions can be investigated, keeping the condenser rating constant. For every cooling plant having the same temperature difference Δt, it is possible to determine the quantity q of circulating water, and the steam consumption K. In a smaller cooling plant, the circulating pump will be of somewhat greater size, and more expensive, while the turbine may be somewhat cheaper, as the final volume of steam will be smaller. The relative alteration of the cost of the circulating pump and the steam turbine may be neglected as compared with the cost differences of the cooling plant.

To find the shortest time of amortisation, by consideration of savings effected, a diagram such as Fig. 13 is drawn, having the annual savings as ordinates and the corresponding amounts of capital invested as abscissæ. The ratio of the amount of capital invested to the savings being in proportion to the time of amortisation, is equal to tan α, as indicated on the diagram. The shortest time corresponds to the tangent to the curve passing through the origin 0 of the co-ordinate system.

For example, suppose that the use of an existing cooling plant would lead to a steam consumption of 6 kg. per kilowatt-hour, the rating of the cooling plant corresponding to the example discussed (for which the time of amortisation is a minimum) could be determined with the aid of Fig. 13, assuming, as above, that the other elements are not changed. The time of amortisation can be calculated, for the known rate of depreciation, from the proportion of the annual savings to the capital invested.

In conclusion, the author would like to express his thanks to Mr. W. O. Skeat, B.Sc. (Eng.), G.I.Mech.E., for assistance in the preparation of the manuscript of this article.

CURVED-TOOTH BEVEL-GEAR GENERATING MACHINES.

THE adjective "curved-tooth" is here used in conjunction with bevel gears not as an alternative to the well-known terms spiral or helical gears, but to distinguish gears in which the tooth is curved along its length apart from any curvature arising from an angular disposition of the teeth on the pitch cone. Such gears require for their formation a tool moving in a curved path and are either generated, or cut directly, by blades arranged at the periphery of a circular cutter head. Although most of the curved-tooth gears produced are spiral gears, *i.e.*, the teeth lie at an angle to the axis of the wheel or pinion concerned, it does not follow that this is the invariable practice, as will be explained later, neither do they always resemble, in respect of angle, the gears usually known as helical bevel gears, the teeth of which are generated by a tool moving in a straight line across the face and offset from the apex of the pitch cone. The curved-tooth bevel gear, though known as far back as 1820, can hardly be said to have been employed practically until nearly a century later, for it was only in 1913 that its formation with a circular

CURVED-TOOTH BEVEL-GEAR GENERATING MACHINES.

CONSTRUCTED BY MESSRS. GLEASON WORKS, ROCHESTER, N.Y., U.S.A.

(*For Description, see Page* 82.)

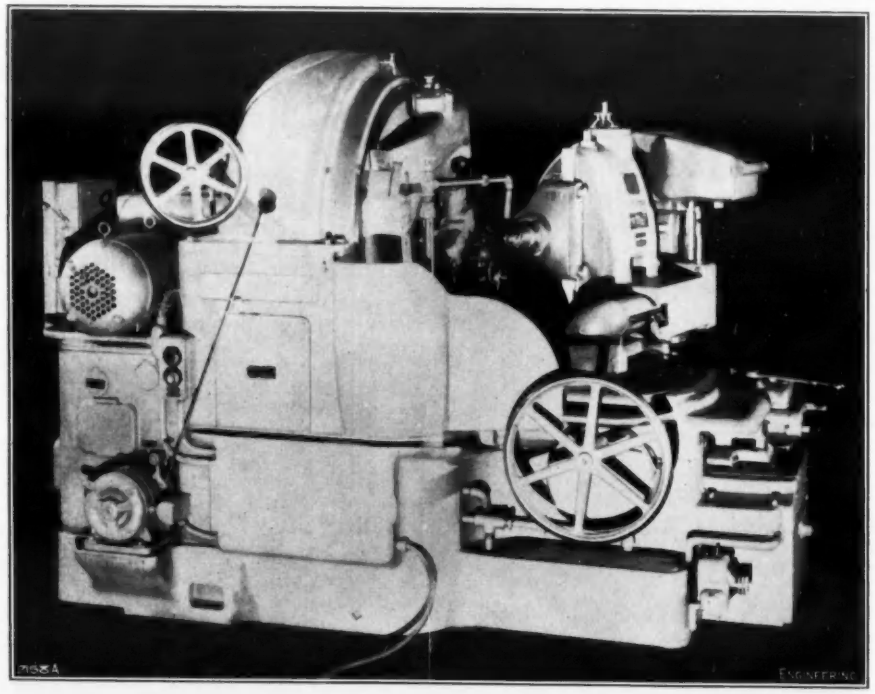


FIG. 1. HYPOID GENERATING MACHINE.

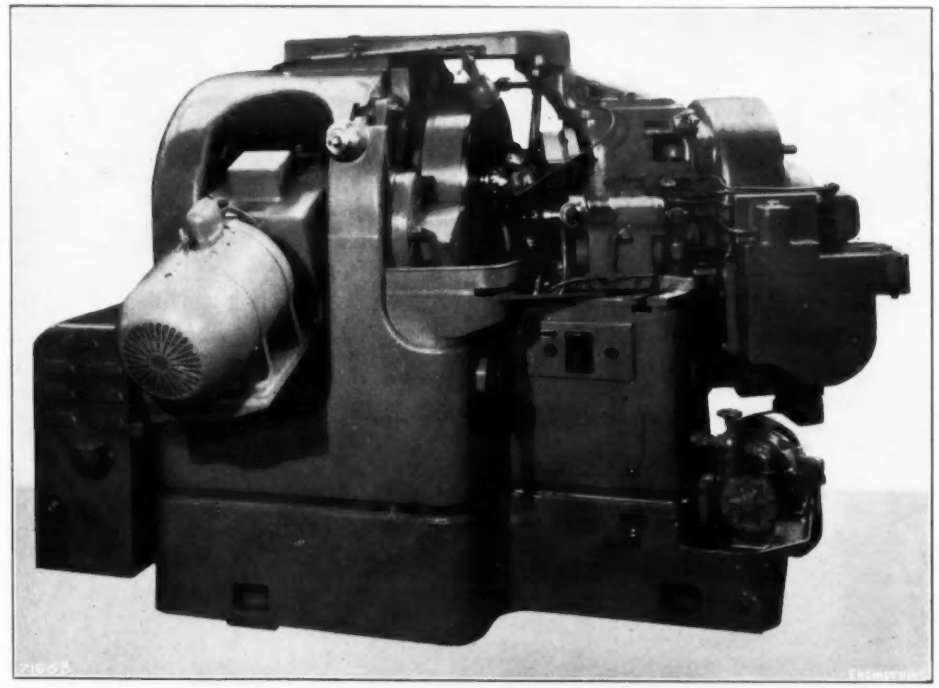


FIG. 2. SINGLE-CYCLE FINISHING MACHINE.

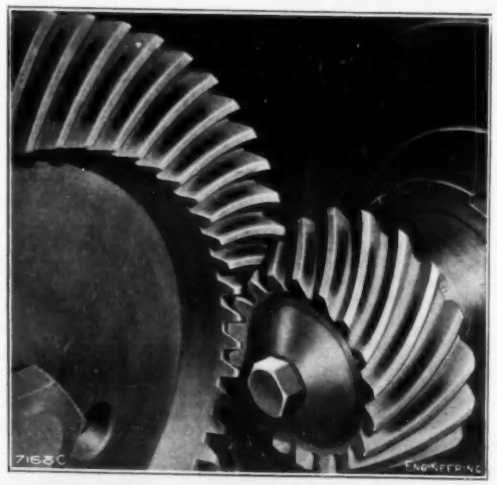


FIG. 3. CURVED-TOOTH SPIRAL-BEVEL GEARS.

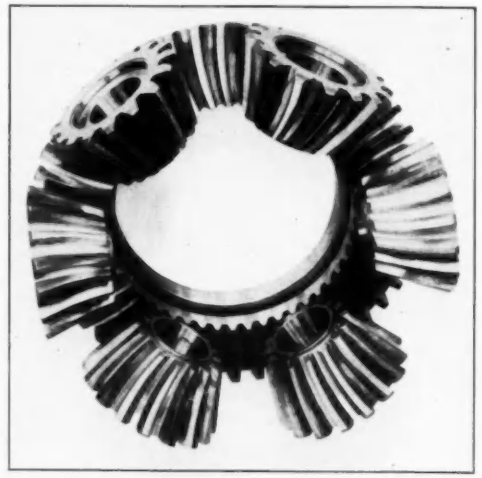


FIG. 4. ZEROL GEAR UNIT.

FIG. 5. INVOLUTE-TOOTH CUTTER.

FIG. 6. SINGLE-CYCLE CUTTER.

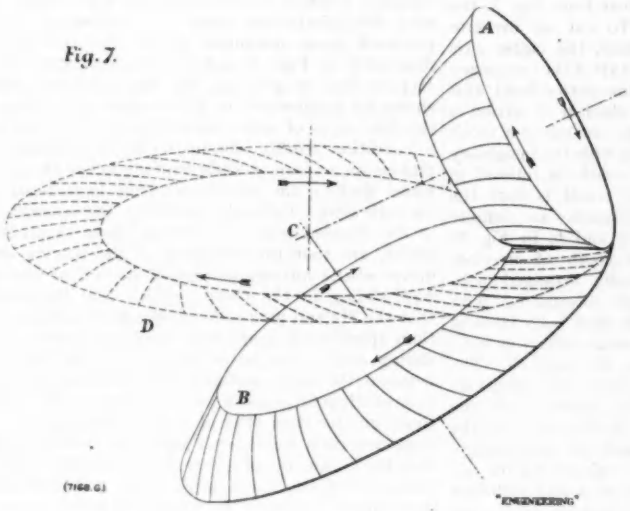
(*To face page* 82.)

UNIV. OF MICH.

CURVED-TOOTH BEVEL-GEAR GENERATING MACHINES.

CONSTRUCTED BY MESSRS. GLEASON WORKS, ROCHESTER, N.Y., U.S.A.

Fig. 7.



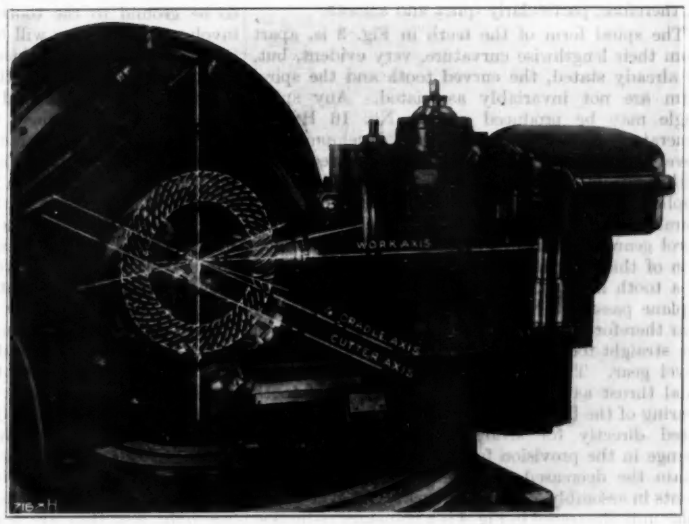


FIG. 8. HYPOID PINION CUT BELOW CENTRE.

Fig. 9.

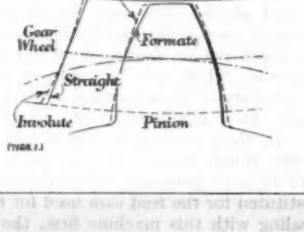


Fig. 10.

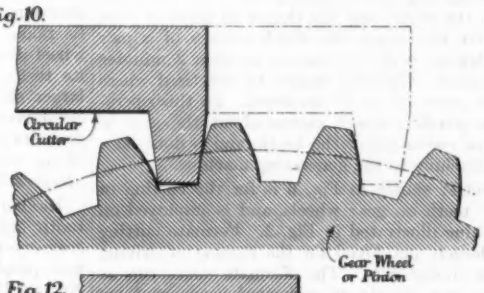
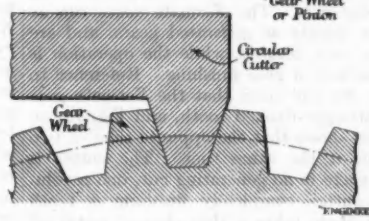


Fig. 11.

Fig. 12.



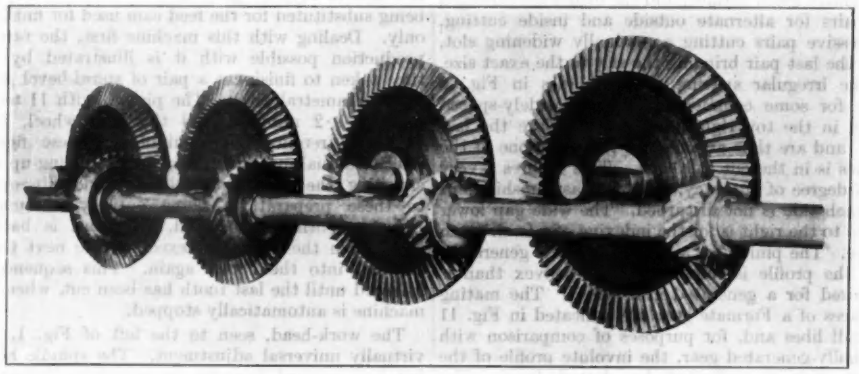


FIG. 13. HYPOID SPIRAL-BEVEL GEAR DRIVE.

cutter made production, on a commercial scale, possible. The development of the curved-tooth bevel gear has, in the main, been due to Messrs. Gleason Works, 1000 University-avenue, Rochester, New York, U.S.A.

The object of the present account is to describe briefly the operating principles of Messrs. Gleason's curved-tooth gear-cutting machines. One of the latest of these machines, illustrated in Fig. 1, Plate V, is classed as the No. 16 Hypoid generator. The term "hypoid," it will be remembered, is used to denote spiral-bevel gears in which the pinion axis lies, not on the gear-wheel axis, but above or below it, and the term "generator" implies that the machine employs a relative rolling motion between the cutter and the pinion or gear wheel being cut, the latter having teeth of involute profile. The machine will, however, cut ordinary curved-tooth spiral pinions and gear wheels, *i.e.*, those in which the axes of the pinion and wheel are coincident. The somewhat similar machine illustrated in Fig. 2, Plate V, this machine also having a circular cutter, is employed for the cutting of what are known as "Formate" bevel-gear wheels, that is, wheels which have curved teeth with straight flanks, and it does not employ a generating motion. The pinions for the "Formate" gear wheels are cut on the "No. 16" machine and may be of either ordinary spiral contour or of hypoid contour. The teeth of such pinions are generated, but the profile departs slightly from a true involute.

At this point it may be of service to review the reasons for the increasing popularity of curved-tooth bevel gears, and in this connection Fig. 3, Plate V, should be referred to. This shows an ordinary curved-tooth spiral-bevel gear, *i.e.*, one with the axes of pinion and gear wheel in the same plane. It will be noticed that in the central part of each tooth flank is a darker area. The teeth, for purposes of investigation, were painted all over with red lead before being run under load, and the dark areas show, by abrasion of the paint, the actual surfaces of tooth flanks which were in contact. These surfaces are obviously in the strongest portions of the teeth. In a straight-tooth bevel gear the contact area theoretically extends for the full length of the tooth and the load is distributed evenly, but a very slight displacement of either the pinion or gear wheel may result in this complete contact not being obtained and, in consequence, the full load may be concentrated at one end or other of the teeth, a condition tending either to cause tooth breakage at the comparatively weak corners or to cause rapid wear due to the squeezing out of the lubricant under the heavy load. Theoretically, the curved-tooth bevel gear should also have contact for the full length of the tooth, but as it is realised that small displacements of mating gears inevitably occur, since no gear mounting or housing is absolutely rigid, the mating teeth are designedly formed by cutters of slightly different diameters, so that the central bearing surfaces indicated by the dark areas of Fig. 3 are obtained. Any displacement of the gears, therefore, simply shifts the area of contact and, of course, the load, somewhat nearer to either end of the teeth, but not right to the weak unsupported areas. The ultimate result is that the gears continue to run without load concentration, a condition, it is claimed, only obtainable with curved teeth. The length of the tooth bearing is made long or short, as demanded by service requirements, by inserting shims under the cutter blades, so providing the alteration in overall cutter diameter desired. It follows from the above that the curved-tooth bevel gear is stronger than one having straight teeth, the characteristic of strength also arising from the fact that there is always more than one

pair of teeth in contact to share the load. Engagement of the teeth is, moreover, effected gradually as one curved surface envelopes the other, in contrast with the instantaneous contact of straight teeth. The drive through the curved-tooth bevel is, therefore, particularly quiet and smooth.

The spiral form of the teeth in Fig. 3 is, apart from their lengthwise curvature, very evident, but, as already stated, the curved tooth and the spiral form are not invariably associated. Any spiral angle may be produced on the No. 16 Hypoid generator; indeed the most recent development in bevel gearing is that of employing curved teeth with no spiral angle at all. The term "Zerol" is applied to such gears from their having zero-degree spiral angle. An illustration of a unit employing Zerol gears is given in Fig. 4, Plate V. Examination of this will show that the centres of each end of a tooth lie in a straight line, which itself lies in a plane passing through the axes of the gear. The gear therefore partakes of the characteristics of both the straight-tooth bevel gear and the curved-tooth bevel gear. Thus the Zerol gears have the same axial thrust as the former and the localised tooth bearing of the latter. They can therefore be substituted directly for straight bevel gears without change in the provision for axial thrust, while they retain the decreased sensitivity to small displacements in assembly, erection or operation. The particular unit illustrated in Fig. 4 is a planetary reduction gear for an aeroplane-propeller drive and provides a large power capacity in a small space and with minimum weight. It would have been impossible to use ordinary spiral-bevel gears because of their inward axial thrust, but at the same time the smoothness and continuity of engagement of those gears was imperative, hence the adoption of the Zerol gears. In the unit illustrated, the gears were ground after hardening in order to eliminate any distortion and to secure the accuracy and uniformity required for the even distribution of the load over the six pinions. The Zerol gear, apart from such applications, is useful in a more commercial way. In certain shops where both straight-bevel gears and spiral-bevel gears are manufactured, the Zerol gear can be used instead of the former, so that only one type of cutting equipment need be installed.

The circular cutter used in generating curved-tooth involute-profile pinions and gear wheels is shown in Fig. 5, Plate V, while that employed for cutting the straight-flanked curved teeth of Formate gear wheels is illustrated in Fig. 6 on the same Plate. The reasons for the differences between the two types will be discussed later; at the moment, it is perhaps better to consider the action of the circular cutter apart from constructional details, Fig. 7 and Fig. 8, page 83, being compared with one another. Referring to Fig. 7, A is a curved-tooth pinion meshing with a curved-tooth gear wheel B, the axes of the two intersecting at the cone apex C. The gears are spiral and either the pinion or the gear wheel can mesh equally well with the crown wheel D, indicated by dotted lines, having its axis also passing through C. The crown wheel is a wholly imaginary element, so it is hardly necessary to point out that the three elements would not mesh simultaneously, or that if the crown wheel meshed with the pinion its teeth would be on the upper face, while, if it meshed with the gear wheel the teeth would be on the lower face. What the diagram is intended to convey is that, if the crown wheel could be arranged to function as a cutter it would form teeth in the gear wheel and pinion which would mesh correctly. This imaginary crown wheel has been drawn, again by dotted lines, on the photograph reproduced in Fig. 8. In this is shown a pinion actually being cut, and the crown wheel is drawn as meshing with it. If, however, the crown wheel revolves on its own centre, *i.e.*, in the direction indicated by the arrows in Fig. 7, a turning action would result, whereas what is required is a cutting action in a path which follows a curved radial line. This action is provided by the circular cutter which is rotated, not on the centre of the imaginary crown wheel, but on one such that its peripheral cutters follow the contour of the teeth of the imaginary wheel; in other words, the whole cutter becomes virtually a single cutting tooth of that wheel. This can be understood quite readily by following, in Fig. 8, the curve of the peripheral cutters, visible in the centre of the imaginary wheel, towards the right hand.

A little consideration will show that if the axis of the cutter is stationary its blades would have to be ground to the tooth profile if this is to be involute, whereas, as will be clear from Fig. 5, the blades have straight sides. To cut an involute tooth with such blades, therefore, the cutter axis must itself be rotated round the axis of the imaginary wheel. The displacement of the cutter head axis from the axis of the cradle in which it is carried is indicated in Fig. 8. During the cutting of a tooth the work is rotated as if in mesh with the imaginary wheel, which means that the cradle is rotated in step with the work. The net result is that the straight-sided blades pass through an infinite number of positions between *a* and *b*, in Fig. 9, page 83, and so generate a tooth of involute profile. The cutters are usually arranged with blades cutting on the outside alternating with blades cutting on the inside, so that both faces of a tooth can be formed by the same cutter, as indicated diagrammatically in Fig. 10, page 83. The teeth having similar cutting faces are identical. Except in the smaller sizes of cutter head, the blades are inserted as shown in Fig. 5. All the blades are of the same size and, in consequence, have equal life. They require sharpening on one face only, and they are relieved in a way such that the diameter and pressure angle remain unchanged by sharpening. The tooth surface is generated by a number of long cuts, sweeping from one end of the tooth to the other, and the degree of finish is such that, after hardening, the tooth surface of a pair can be lapped perfectly smooth in from 2 minutes to 4 minutes. Grinding should be practised where precision gears are to be hardened. In this operation the grinding wheel moves about the axis of lengthwise curvature of the tooth, and is done on a similar machine to the generating machine.

The cutter shown in Fig. 6 is for the cutting of Formate teeth on gear wheels, and is employed on the machine illustrated in Fig. 2. Formate cutting is now largely employed for the cutting of driving gears for motor cars. The Formate gears run as smoothly and quietly as generated gears, and are equally strong and durable, while the operation is the fastest method of gear finishing. Reference to Fig. 11, page 83, will show that the Formate gear wheel has a straight-flanked tooth, and Fig. 12, on the same page, shows that the opposite sides of two teeth are cut at the same time. The cutter is circular, but there is no generating cut, one revolution of the cutter completely finishing a tooth space. Each blade takes a thin chip of metal off the entire tooth surface, and the blades are arranged in pairs for alternate outside and inside cutting, successive pairs cutting a gradually widening slot, and the last pair bringing the slot to the exact size.

The irregular spacing of the blades in Fig. 6 calls for some comment. The two widely-spaced teeth in the top right-hand quadrant are the last pair, and are thus arranged so that only one of the blades is in the cut at a time. This ensures a very high degree of accuracy, since the last finishing cut on each side is not disturbed. The wide gap lower down to the right is for the indexing of a fresh tooth space. The pinion for a Formate gear is generated, but the profile is somewhat more convex than is required for a generated gear wheel. The mating surfaces of a Formate gear are indicated in Fig. 11 by full lines and, for purposes of comparison with a wholly-generated gear, the involute profile of the latter gear is indicated by dotted lines. The difference between the profile for a wholly-generated pinion and a Formate pinion is, however, nothing like so great as shown in Fig. 11. This difference, on a generated gear 10 in. in diameter and having a 4 to 1 ratio amounts only to from 0·003 in. to 0·005 in. It may be mentioned that, although Formate cutting is only a few years old, it is stated that fully 93 per cent. of new American motor cars have their rear-axle gears cut by this method. A large proportion of such gears are ground after hardening.

The Hypoid curved-tooth gear referred to earlier was introduced in 1925, and its adoption enabled lower bodies to be fitted to motor cars. Again, citing practice in the United States, it is recorded that in the year 1938, 77 per cent. of the cars in that country were built with hypoid rear-axle drives. The Hypoid gear is generally similar to a curved-tooth spiral gear, and may, of course, be cut, and, in some cases, ground, by either the generating or Formate method on the same machines that are used for spiral-bevel gears with coincident axes, provided these machines are of the new types illustrated in Figs. 1 and 2. An illustration of a Hypoid bear is given in Fig. 13, page 83. This shows an application to a wire-drawing machine, the four units of which must be accurately timed, a condition readily obtainable by mounting the pinions on a common shaft running below the gear-wheel shafts; the wheels can thus have bearings on both sides. Generally speaking, the advantages of the Hypoid gear, apart from those mentioned above, are that the offsetting of the driving and driven shafts introduces a small amount of lengthwise sliding in the tooth action, with the result that the Hypoid gear is even smoother and quieter than spiral-bevel gears with coincident axes. The sliding action also helps to maintain an oil film between the tooth surfaces. The fatigue life of a pair of Hypoid gears is stated to be at least four times greater than that of a corresponding pair of coincident-axis spiral-bevel gears, the reason being that the fatigue life of a pair depends on the smaller member. Since, for a given ratio and the same gear-wheel diameter, a Hypoid pinion is from 20 per cent. to 30 per cent. larger in diameter than that of the corresponding ordinary pinion, it is, therefore, stronger. Advantage should not, however, be taken of this characteristic to reduce the gear-wheel diameter, as this would increase the load on its teeth. Moreover, the larger pinion permits a larger shank to be used or a bored pinion to be employed. Thus, certain high ratios which were undesirable with coincident-axis spiral gears because of the prohibitively small diameters of the pinions are possible with Hypoid gears.

Having now dealt with the principles of curved-tooth spiral-bevel gear production, the machines concerned may now be briefly described. In the first place, it should be understood that both the No. 16 Hypoid generator, Fig. 1, and the single-cycle finishing machine, Fig. 2, are precision machines and should, therefore, be employed to make finishing cuts only, the gear blanks being previously rough cut on similar machines designed for this purpose. There may be instances, however, where the quantity of gears required is not sufficient to warrant the installation of rough-cutting machines. In these cases gear wheels and pinions can be both rough rough cut and finish cut on the No. 16 Hypoid generator, a suitable feed cam being substituted for the feed cam used for finishing only. Dealing with this machine first, the rate of production possible with it is illustrated by the time taken to finish-cut a pair of spiral-bevel gears of 4·5 diametral pitch. The pinion, with 11 teeth, requires 9·2 minutes, and the gear wheel, with 41 teeth, requires 20·6 minutes. These figures refer to actual machining times after setting-up and chucking, the operation of the machine subsequent to these preparations being entirely automatic. After a tooth is generated, the work is backed away from the cutter, indexed for the next tooth and fed into the cutter again. This sequence is followed until the last tooth has been cut, when the machine is automatically stopped.

The work-head, seen to the left of Fig. 1, has virtually universal adjustment. The spindle housing has vertical traverse on a column which is carried on a saddle provided with both horizontal traverse and a swinging movement through a horizontal arc. The vertical traverse enables a Hypoid pinion to be cut in an offset position corresponding to its working position. Index change gears for various numbers of teeth are conveniently placed at the rear of the head near the index dividing wheel, which rotates in an oil bath. The index worm is integral with its shaft, is hardened and ground, and is carried in matched anti-friction bearings. A scale and vernier enable the work head to be set with great accuracy, and a dial and vernier being provided on the rear of the work spindle for checking the indexing and ratio of roll. The longest

550-H.P. BATTERY SHUNTING LOCOMOTIVE FOR THE L.P.T.B.

(*For Description, see Page* 85.)

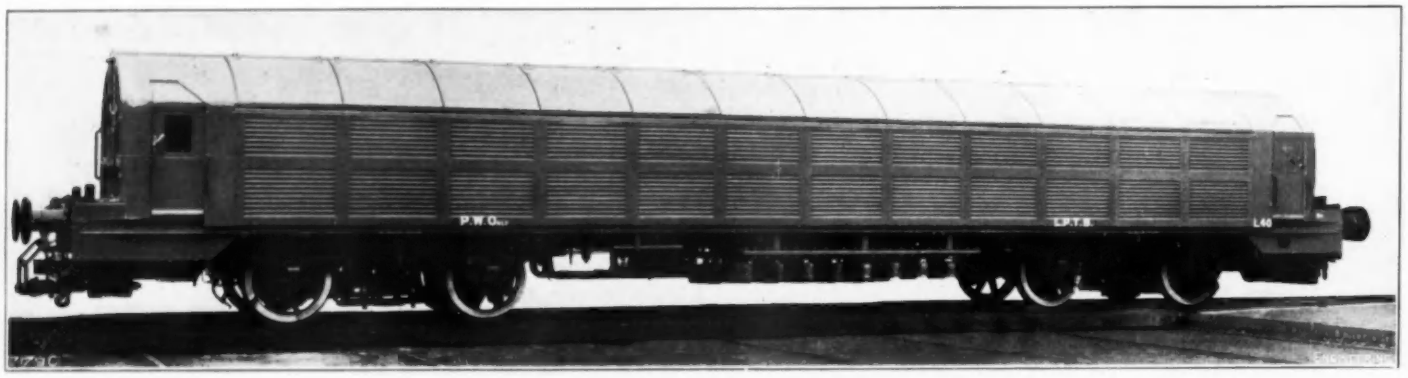


FIG. 5. SIDE VIEW OF LOCOMOTIVE.

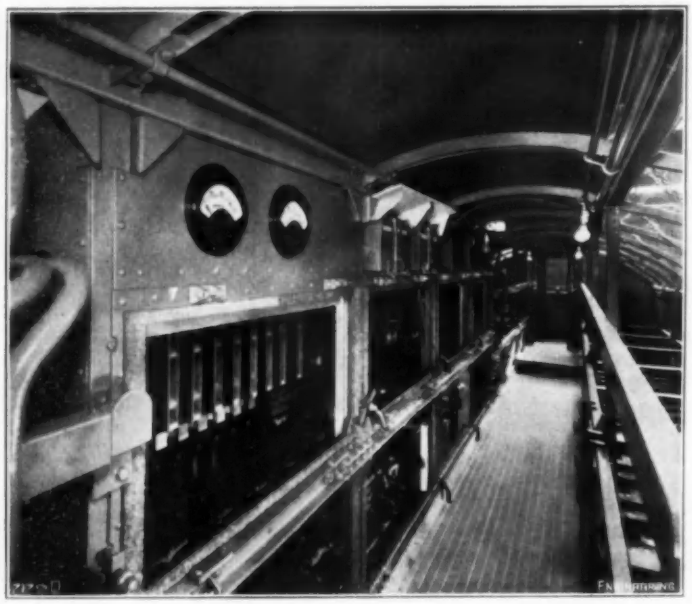


FIG. 6. INTERIOR OF CENTRAL COMPARTMENT.

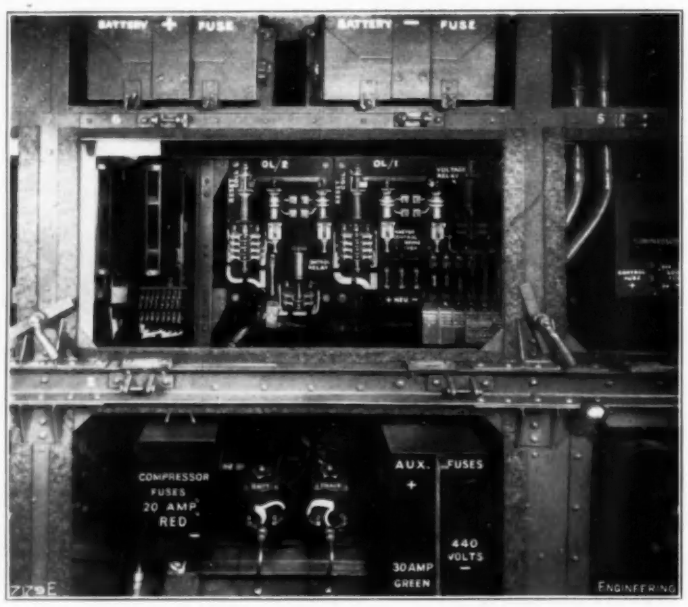


FIG. 7. CENTRAL PART OF APPARATUS COMPARTMENT.

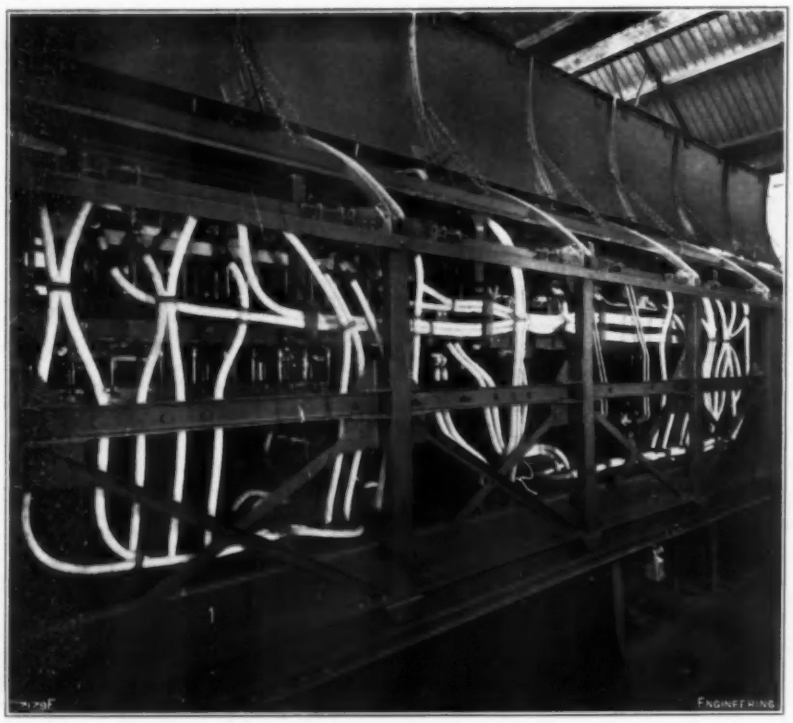


FIG. 8. REAR PART OF APPARATUS COMPARTMENT.

FIG. 9. DRIVER'S CAB.

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UNIV. OF MICH.

550-H.P. BATTERY SHUNTING LOCOMOTIVE FOR THE L.P.T.B.

Fig. 1.

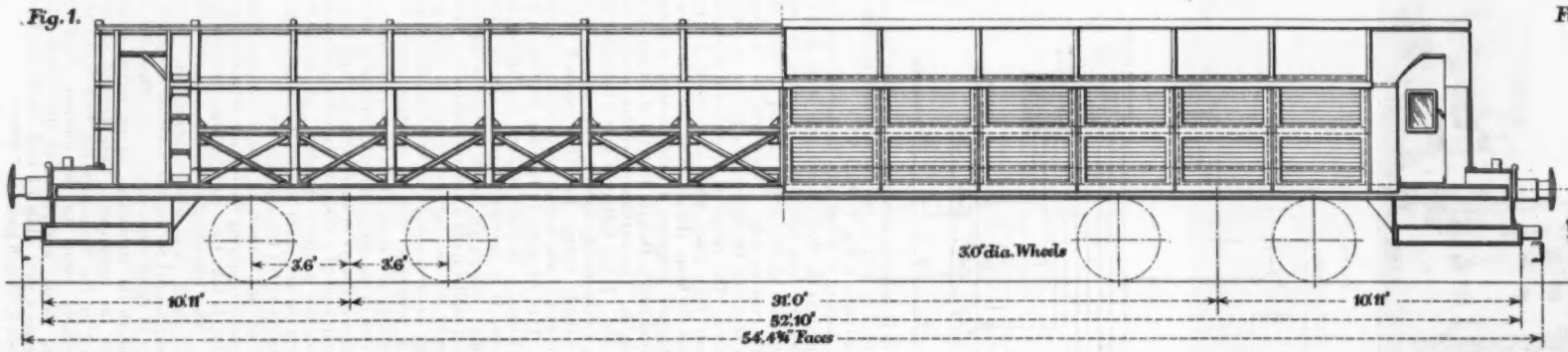


Fig. 2.

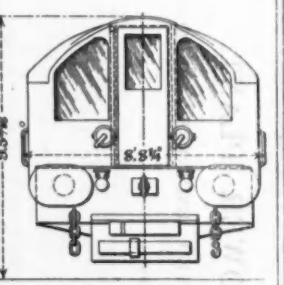


Fig. 3.

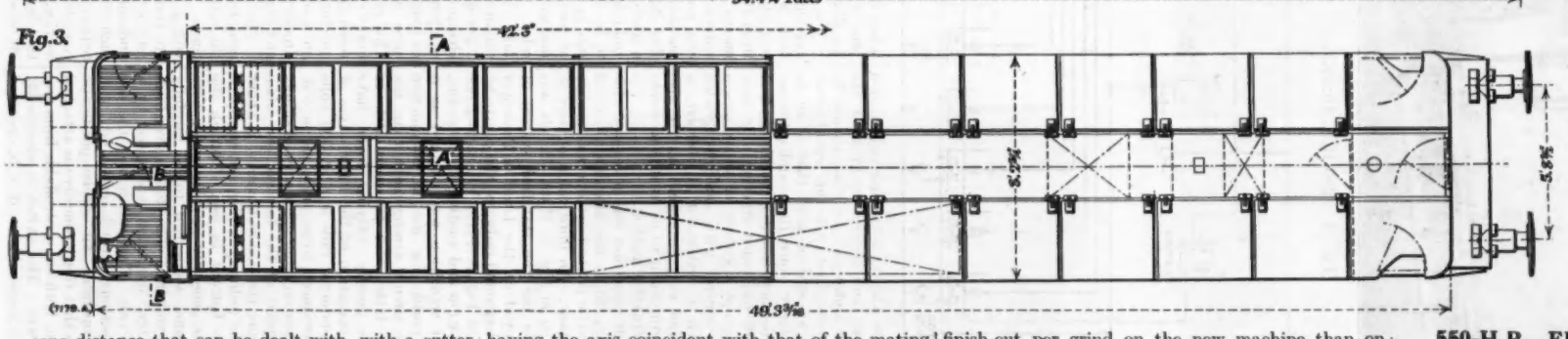
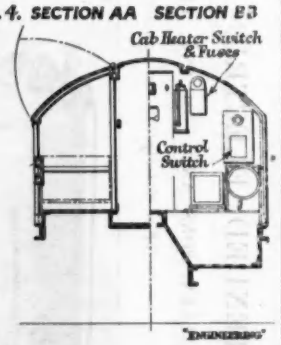


Fig. 4. SECTION AA SECTION BB



cone distance that can be dealt with, with a cutter 12 in. in diameter and a spiral angle of 30 deg., is 9 in. With shafts at 90 deg. the pitch angle may be varied within 5 deg. 42 minutes and 84 deg. 18 minutes, and the largest pitch diameter possible, with a 10 to 1 ratio gear, is 18 in. With a 1 to 1 ratio gear the largest pitch diameter is $12\frac{3}{4}$ in. The maximum full depth of tooth that can be cut is $\frac{3}{4}$ in., and the maximum face length is $1\frac{3}{8}$ in., when a 20-blade cutter 12 in. in diameter is being used, and the spiral angle is 35 deg. The work spindle can be set between the maximum offsets of $3\frac{1}{2}$ in. above the mating gear-wheel centre and $3\frac{5}{8}$ in. below that centre. The saddle is given feeding traverse by a cam situated underneath it. Variable feed is provided and the automatic stop is actuated by the feed cam. The indexing and reverse mechanisms are hydraulically cushioned.

The cutter cradle differs radically from the design employed in previous machines. It is circular and is mounted in anti-friction bearings in a rigid housing. The circular construction provides the same degree of support in all positions of the generating roll. The cutter spindle is carried in a slide in the cradle on large pre-loaded anti-friction precision bearings, so that it can be offset from the cradle centre and can be adjustable angularly in a vertical plane. The axis can also be set at an angle. These adjustments are essential for the correct cutting of a Hypoid pinion but are, at the same time, of considerable advantage in cutting spiral-bevel pinions having the axis coincident with that of the mating gear-wheel. The cradle roll is controlled by change gears. The drive from the motor, which is of 3 h.p., for the finishing machine, is transmitted through spiral-bevel gears. The cutter-speed gears and work-feed gears are contained in the same transmission unit. The direction of rotation of the cutter is changed by reversing the motor rotation by means of a two-way switch. The cutter speed naturally varies with its diameter, but with the three diameters of cutter normally used on the machine, viz., 6 in., 9 in., and 12 in., the speeds lie between the extremes of 64 ft. and 236 ft. per minute. One size of cutter can be used on a wide range of pitches and gear diameters; thus only ten standard cutter diameters cover the entire range of gear diameters from $\frac{1}{16}$ in. to 30 in., this last size being the largest curved-tooth gear that it has been found commercially practicable to cut with circular cutters. Spiral-bevel gear wheels up to 120 in. in diameter are, however, accurately cut on planing generators using a single tool. The new design of machine shown in Fig. 1 is stated to produce a better tooth bearing and finish than could be obtained on the earlier patterns. The machine can, moreover, be operated at much higher speeds and the handling time required to remove a finished cut gear and to replace it with an already roughed-out blank has been reduced by about 75 per cent. The increased rigidity and accurate mounting of the cradle unit enable from 30 per cent. to 50 per cent. more gears to be finish-cut per grind on the new machine than on the previous types.

The single-cycle finishing machine shown in Fig. 2, since the circular cutter is not made to generate the teeth of the work, is much simpler and faster to operate than the machine shown in Fig. 1. A 41-tooth gear of $4\frac{1}{2}$ diametral pitch can be finish-cut on it in 3·4 minutes after being rough-cut on a companion machine in 3·9 minutes. In both machines particular attention has been paid to the lubricating- and cutting-oil supplies, the pumps for both supplies being driven by an independent motor which is started and the lubricating-oil pressure increased to the required value before the main motor drive can be started. Control is by push button.

HEAT-RESISTING STEELS.—Messrs. Hadfields, Limited, East Hecla Works, Sheffield, have recently published a brochure dealing with the properties and uses of their "Era H.R." heat-resisting steels. These materials are stated to maintain high rigidity and freedom from appreciable scaling at temperatures up to 1,150 deg. C., and to be highly resistant to sulphurous atmospheres and to a wide range of corroding agencies. The steels are produced in the form of castings, forgings, rolled bars, sheets, tubes and wire, and examples of their use for burner nozzles, furnace-conveyor chains, retorts, superheater-element spacers and tube supports, case-hardening boxes, reheating-furnace pusher bars, hardening pots, furnace grilles and other equipment for high-temperature work, are given in the brochure. The physical and mechanical properties and creep strength are also dealt with.

550-H.P. ELECTRIC BATTERY SHUNTING LOCOMOTIVE.

THE large amount of constructional work which has been undertaken by the London Passenger Transport Board during the past few years, especially in connection with the lengthening of the platform tunnels at certain stations, has necessitated some interesting arrangements being made for the transport of the spoil and of the materials required. This work, which includes the picking up and unloading of rails, sleepers and ballast at different places on the route, as well as rail and cable laying, concrete-mixing, ballast-spreading and shunting, is effected by six battery locomotives, the general layout and mechanical portion of which are due to Messrs. The Gloucester Railway Carriage and Wagon Company, Limited, Gloucester, while the electrical equipment was supplied by Messrs. The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2. These locomotives, of which particulars are given below, have now been in operation for over a year and are, we understand, giving very satisfactory results.

The design of these locomotives will be clear from Figs. 1 to 4, on this page, while their appearance is shown in the two views reproduced in Fig. 5, on Plate VI, and in Fig. 10, on page 90. The length over the body and panels is 49 ft. $3\frac{3}{16}$ in., over the headstocks 52 ft. 10 in., and over the coupler faces 54 ft. $4\frac{1}{4}$ in. The distance between the centres of the bogies, which have a wheel base of 7 ft., is 31 ft. The overall height from the rail to the top of the roof sheet is 9 ft. $5\frac{5}{16}$ in., and the width over the body pillars is 6 ft. $2\frac{3}{4}$ in. The total weight in running order is 52 tons 6 cwt. The locomotives are of all-steel construction, as shown

generally in Figs. 1 to 4. The underframes are constructed of rolled-steel sections, which are riveted together and are designed to carry the electrical equipment, air compressor and power brake, while the bogies, which were supplied by the London Passenger Transport Board, are of the pressed-steel type. Certain of the body framing members are covered by ebonite channels to protect them from the acid and all the interior steelwork is treated with acid-resisting enamel. Dual draw and buffing gear is fitted to suit both main-line and Tube running conditions. When running in the Tubes, the side buffers, which are of the self-contained type, are hinged back on to the top of the headstocks, so that the standard automatic couplers can be used. For main-line service, these buffers are lowered to the standard running position and are used in conjunction with the normal drawbar and three-link coupling. In the latter case, the automatic coupler is pivoted out of centre and locked against movement by means of a pin.

As will be seen, a driver's cab is provided at each end. This is fitted with two side doors, one end door and windows. Each door is of the hinged type and has drop lights, but the end windows are fixed, that immediately in front of the driver being of Triplex glass. Each cab is partitioned off from the main compartment, which is arranged for housing the batteries; these weigh about 13 tons. The main compartment also incorporates a smaller compartment, about 14 ft. long and 2 ft. 9 in. wide, in which the switchgear and other electrical equipment is accommodated. A view of this central compartment, showing the apparatus cubicles with the air-tight covers removed on the left and the battery-containing structure on the right, is given in Fig. 6, Plate VI. The floor is constructed of lead-coated steel sheets as a protection from acid, and drain outlets are provided at suitable places along the central gangway, which extends the whole length of the locomotive. The floor of this gangway is covered with the Board's standard wood lagging in maple, the same material also being used in the driver's cab. The gangway level is about 6 in. lower than that of the battery floor in order to give extra headroom. The body sides are sheeted with detachable metal louvre frames for ventilation, while the side roof is made into doors above the batteries, so that the latter may be lifted out. All the body panels are of mild steel. The centre portion of the roof, which extends the length of the gangway is, however, fixed. The exteriors of the locomotives are finished in glossy Transport grey.

Sanding gear is fitted to each bogie, there being a sand pipe to each wheel at the outer end, and is operated by a foot pedal in the driver's cab. A whistle fitted under the floor of each cab is also pedal-operated. Two headlights are provided at each end of the locomotive and are each fitted with a clear-glass slide. Two portable headlights with flexible leads and plugs are also available. In addition to the master controller, the function of which is described in more detail below, each cab contains the driver's brake valve, guard's emergency valve, hand-brake lever, fire extinguisher, electric heater and candle lamp for emergency use. A two-way switch is provided for changing over from cab to instrument lighting and suitable lamps are arranged along the gangway for illuminating the driver's compartment.

It was specified that two locomotives, one at each end of the train, should be capable of hauling trailing loads of 200 tons up a gradient of 1 in 61 with occasional gradients of 1 in 40. They were also to be able to inch forward a train up a gradient of 1 in 30 on a rough constructional track on which one sleeper might be ¼ in. above or below the next. Finally, they were to be capable of hauling 100-ton trains for cable laying at steady speeds of between 2 m.p.h. and 3 m.p.h. without jerks. Actually, the total weight of a train is about 300 tons and operates over a distance of some 14 miles.

All these requirements were to be met whether the locomotives were supplied from the conductor rails or from the batteries and the batteries themselves were to be capable of being recharged in twelve hours and to be able to supply sufficient energy to operate the train throughout a duty period of nine hours. In meeting these requirements, which are, of course, outside the normal service conditions of electric locomotives, many problems of design were encountered. One of the principal of these, particularly in its effect on the control gear, was to obtain slow running combined with smooth operation.

To fulfil these conditions, the London Passenger Transport Board decided to equip each locomotive with four 138-h.p. 600-volt direct-current motors, and for reasons of uniformity stipulated that these motors should, except for the axle bearings, be identical in type with those supplied by Messrs. The Metropolitan-Vickers Electrical Company, Limited, for Metadyne operation. They are supplied at half voltage from a 160-cell lead battery with a capacity of 760 ampere-hours, or at full voltage from the conductor rail. As regards the control gear, it was at first proposed that, as there was some doubt whether a locomotive provided with resistance starting and control could meet the specified conditions, a motor-generator set should be used. It was felt, however, that to do this would result in a reduction of the amount of work that could be obtained from the battery, since the stand-by losses and lower running efficiency would more than offset the efficiency losses in resistance starting. It was, therefore, decided to adopt a system of series, series-parallel and parallel control with carefully graded resistance steps. Such a system, it is claimed, is simple in operation and easy to maintain. It also enables much lighter equipment to be used than would be required by the alternative method.

Though multiple-unit operation was necessary, this presented no difficulty, since the standard General Electric electro-pneumatic control system was readily adaptable for the purpose. An illustration of part of this equipment is given in Fig. 8, Plate VI. It was also found possible to use the standard system of driver's control employed on the London Passenger Transport Board's underground railways, the controller in the cab, as shown in Fig. 9, Plate VI, having one handle for speed regulation and another for reversing. The shunt method of transition was adopted as it is more readily adaptable for use in conjunction with the three-motor circuit arrangement than the bridge method. The latter also possesses little or no advantages when greatly varying loads have to be handled. The operation of the locomotives at 600 volts from the conductor rails and at 300 volts from the batteries introduced some problems in connection with the change-over from one source of supply to the other. The speed of the locomotives, when taking their supply from the conductor rails, is about the same as that of the ordinary traffic, but would be much lower with the battery in use. Though the control equipment was generally suitable under both conditions, the resistance steps had to be carefully graded to suit the two voltages. The change-over from conductor rail to battery operation is effected by a master switch in each cab. This switch is of the key type and has three positions, "track on," "off," and "battery on." It operates an electro-pneumatic change-over switch, so that if a locomotive is attached to each end of the train, both are controllable from any of the four driver's cabs. The switch is electrically interlocked, so that it is impossible for it to be operated when it is carrying current. The relays for overload protection as well as the battery and auxiliary fuses are illustrated in Fig. 7, Plate VI.

The battery is fitted into hardwood crates and is supported on the floor at each side of the gangway by teak bearers, from which it is separated by porcelain insulators, as shown in Figs. 3 and 4. It is charged from the running rails. When once put on charge by means of a suitable switch, the process is completely automatic. The circuit is so arranged that charging can only take place when no current for traction purposes is being drawn from the conductor rails. For charging purposes, a series resistance is inserted, a method which, though wasteful of energy, is simple and reliable. This enables one of three rates of charging to be used. If the battery is fully discharged, the full rate is automatically applied, while as soon as a state of two-thirds charge has been reached the intermediate rate is also automatically applied by a voltage relay. This continues to function until the battery is fully charged. In order to keep the battery in good condition, it is necessary periodically to give it a "gassing" charge, for which purpose a third rate of charging can be applied non-automatically. Protective equipment for the battery circuits is provided and includes an arrangement whereby the charging resistance is protected from overheating during charge. This consists of a relay which temporarily introduces a lower rate of charging. Since a fairly large amount of resistance is always in series with the battery and the automatic control is based on the voltage of the battery on load, the complete charging cycle has a suitable drooping current characteristic, beginning with a high and ending with a low charging rate.

The lighting circuits of the locomotives and the compressors supplying the compressed air for operating the contacts take their current from the battery at all times. The considerable variations in the battery voltage which occur when charging and discharging are compensated for by the insertion or removal of a number of small series resistances. These are carried underneath the locomotive, as are certain auxiliaries, such as the compressor. The amount of charging required by the locomotive has been found to vary considerably owing to the different conditions of service. On day work, however, the average is 3 hours to 4 hours a day, while for night work this has to be increased to from 6 hours to 7 hours.

UNATTENDED ELECTRIC POWER PLANT.

MESSRS. W. H. ALLEN, SONS AND COMPANY, LIMITED, ENGINEERS, BEDFORD.

(*For description see opposite page.*)

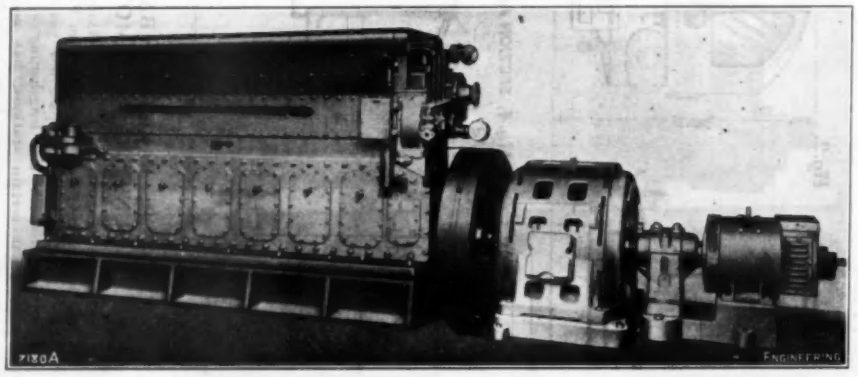
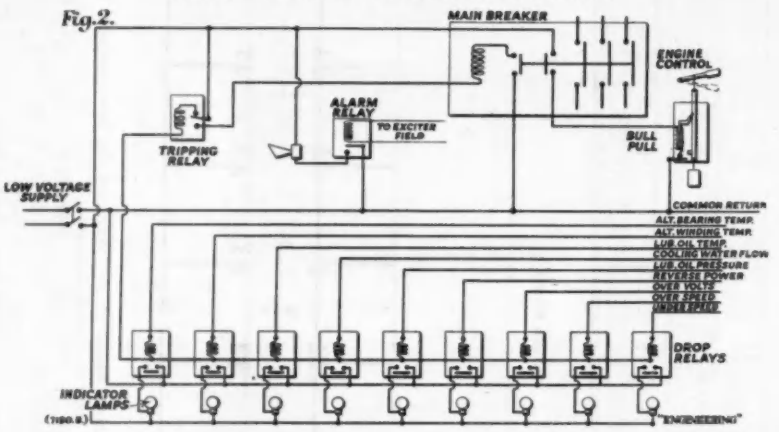


FIG. 1. 266-H.P. OIL-ENGINE AND ALTERNATOR.

Fig.2.



UNATTENDED ELECTRIC POWER PLANT.

MESSRS. W. H. ALLEN, SONS AND COMPANY, LIMITED, ENGINEERS, BEDFORD.

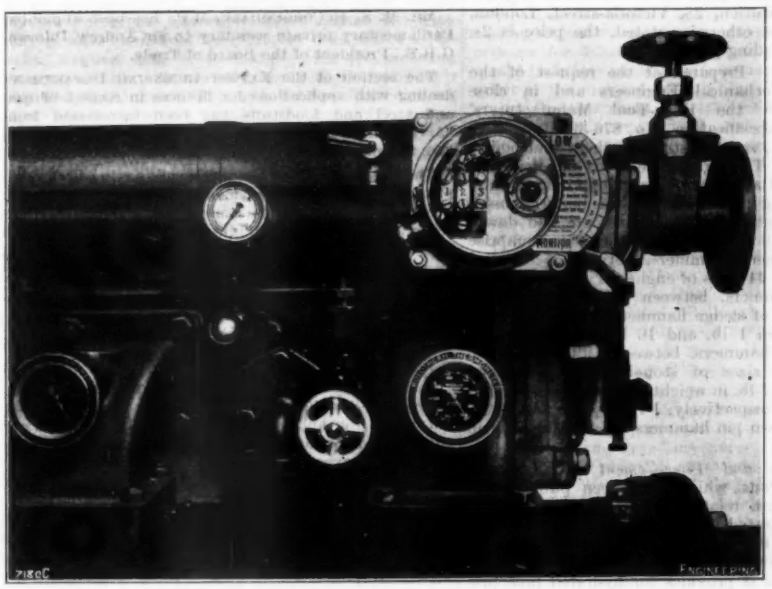


FIG. 3. FLOW INDICATOR ON COOLING-WATER OUTLET.

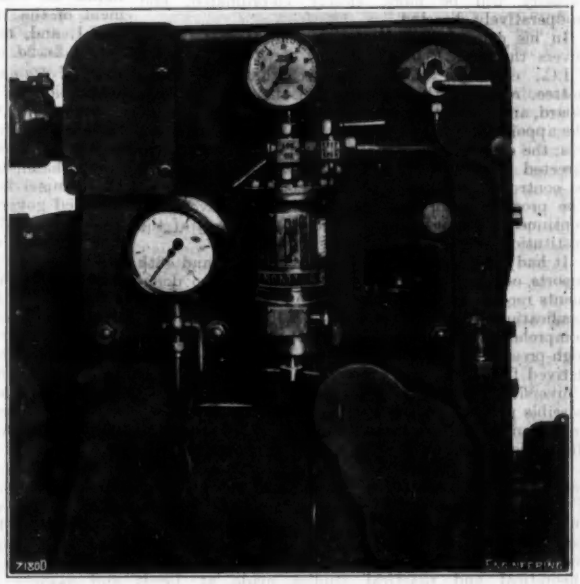


FIG. 4. ALARM IN LUBRICATING-OIL MAIN.

UNATTENDED ELECTRIC POWER PLANT.

WHERE plant for the generation of electricity is installed in remote locations there are obvious economic advantages in designing it so that it can operate unattended for prolonged periods. This applies whether the generator is driven by water power, steam or internal-combustion engines, and considerable success has been obtained with all three types of prime mover, though the details of the equipment necessarily vary in each case. For instance, though the oil engine is inherently reliable from the mechanical point of view, there are a limited number of vital services upon it which must be maintained if damage is to be avoided. If a fault on any of these occurs, the plant must be shut down without delay, while the attendant, who may be some distance away at the time, should be informed of what has happened and when he arrives at the station he should be able to ascertain the nature of the fault.

How these conditions can be met may be illustrated by referring to an installation which has recently been carried out in a mining district in South Africa by Messrs. W. H. Allen, Sons and Company, Limited, Bedford. This comprises a 266-brake horse-power seven-cylinder oil engine of the firm's S 30-B type, running at a speed of 600 r.p.m., and direct-coupled to an alternator with an output of 184 kW. As this set, which is illustrated in Fig. 1, opposite, was required to run unattended, protection had to be provided against the alternator pedestal bearing becoming overheated and against an excessive rise in the temperature of the alternator windings. Similarly, an excessive rise in the temperature of the lubricating oil and complete or partial failure of the cooling water or lubricating-oil pressure had to be guarded against, while precautions had to be taken to prevent a reversal of power when the set was running in parallel with others, against over-voltage caused by the failure of the automatic voltage regulator, against overspeed of the engine, due to a faulty governor, and against overload or underspeed. To take care of the various temperature conditions mentioned, thermostats are therefore located in the alternator bearing housing and alternator windings, as well as in the return pipe between the engine sump and the oil tank. On the temperature rising above a pre-determined value at any of the places thus protected, the appropriate thermostatic contacts are closed and, as shown in Fig. 2, a circuit is completed through a drop relay on an alarm panel and through a tripping relay on the alternator contact breaker. These drop relays control a series of red lamps on the alarm panel.

Similarly, to protect the engine against the cessation or reduction of cooling-water flow, an adjustable flow meter of the Monitor type, which is fitted with electrical contacts, is placed in the outlet main, as shown in Fig. 3. If, then, the rate of flow falls below a predetermined dangerous limit, the contacts will close and an alarm be given, as in the case of the temperature rises already mentioned. A second Monitor alarm, which is illustrated in Fig. 4 and is set to complete the circuit at a pre-determined low limit of pressure, is placed in the oil main, which supplies forced lubrication to all the principal bearings. Protection of the plant against reverse power, over-voltage and electrical overload is, of course, effected by devices of standard design, which are incorporated in the alternator switchgear.

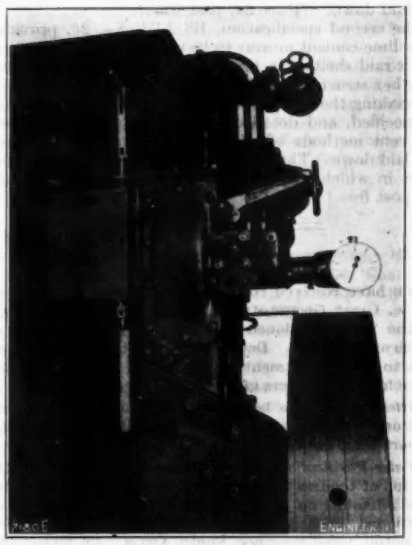


FIG. 5. "BULL-PULL" DEVICE ON FUEL CUT-OFF LEVER.

The conditions of excessive speed or underspeed are met by means of a centrifugal switch, which is driven from an extension of the alternator shaft. At the normal operating speed of 600 r.p.m., the weights of this switch run in such a position that an arm floats between two contacts, but in the event of any abnormal increase or decrease above this figure it touches one or other contact and the appropriate alarm circuit is closed. When a tripping relay comes into action as the result of any of the occurrences described, the main contact breaker is tripped, thus taking the alternator off the 'bus bars and at the same time interrupting the current to the alarm device. An additional contact is also provided on the main circuit breaker. This is used to energise the engine shut-down relay circuit. A device, known as a "Bull Pull," is attached to the fuel cut-off lever on the engine, as illustrated in Fig. 5. When the fuel cut-off lever is placed in the running position, a heavy weight beneath the "Bull Pull" is raised and a latch holds the control in position. When the circuit-breaker is released by the tripping relay, the additional contact energises an electro magnet in the Bull Pull, thus releasing the weight, which acts on the fuel cut-off lever and shuts down the engine. The Bull Pull is arranged to break its own circuit after operation.

To sum up, it will be clear from what has been said above that if any one of nine failures or partial failures occurs the appropriate red lamp on the alarm panel is lighted by the operation of the associated drop relay, while the tripping relay is energised and the main circuit breaker opened. In addition, the engine is shut down. Finally, a warning is given to the engine attendant through an alarm relay, which is held closed by the alternator-exciter voltage. Immediately the exciter ceases to generate, the relay arm is released, and a contact is made in the battery circuit, causing an electric horn to be sounded. This horn can be placed in any convenient position so as to be readily audible to the attendant. To enable the plant to be started up normally, a tumbler switch is provided to render the safeguarding circuits temporarily inoperative. The current for the alarm devices and signal lamps is supplied from a 24-volt accumulator.

THE INSTITUTION OF GAS ENGINEERS: REPORT OF THE RESEARCH EXECUTIVE COMMITTEE.

THE President of the Institution of Gas Engineers, Mr. George Dixon, B.Eng., M.Inst.C.E., has contributed a short historical foreword to the 5th Report of the Institution's Research Executive Committee, in which he has traced the organised research of the gas industry. Many suggestions to that end had been made before, in 1906, under the stimulus of the late Dr. Charles Carpenter, the Special Purposes Fund of the Institution was started and it became possible to follow up the earlier intentions. The endowment, in 1910, of the Livesey Professorship of Coal Gas and Fuel Industries, at Leeds University, was a pioneer step in reconciling the industrial and academic outlooks, and was the starting point of an unbroken and very successful collaboration between the Institution and the University. The co-ordination of these investigations was organised in 1929 with the establishment of the General Research Committee of the Institution, which published its first report in 1930; this was superseded, in 1934, by a Scheme of Research and Technical Organisation, operated by the Council of the Institution through a Research Executive Committee. In June, 1939, the Gas Research Board was set up, which is representative of all interests in the gas industry. Thus, the Research Executive Committee, after five years of extremely useful service, hands

on the torch to the Council of the Gas Research Board, upon which its members will find themselves reinforced by prominent representatives, experienced in research, of the plant and appliance manufacturers. Henceforth, research applied to the countless problems of the gas industry will be more closely co-ordinated, and co-operatively directed.

In his general introduction to the Report, which covers the year 1938-39, Mr. E. V. Evans, O.B.E., F.I.C., chairman of the Research Executive Committee, refers to the formation of the Gas Research Board, and recounts how the outbreak of war prevented the appointment of a Director of Research. Nevertheless, the change-over was made, and the work hitherto directed by the Research Executive Committee will be controlled, in future, by the Gas Research Board. The progress reports of investigations, however, will continue to be published in the Transactions of the Institution of Gas Engineers.

It had been hoped to present, in the 45th and 46th reports of the Joint Research Committee, two documents recording distinct advances in knowledge of the gasification of coal. The draft 45th Report contains a comprehensive and critical survey of the possibilities of high-pressure gasification, based upon the knowledge derived from experimental work carried out at Leeds University. It draws attention to those features of possible processes where trouble is likely to be experienced, and suggests a means of avoiding these potential difficulties. The draft 46th Report is concerned with a study of the mechanism of the reactions between carbon and the gases, carbon dioxide and water vapour. The physical chemistry of these reactions has been the subject of much prior work, but, hitherto, there has been no means of reconciling the diverse conclusions reached by different investigators. As the result of theoretical and practical studies made at Leeds University, a reconciliation has now been achieved and a much clearer picture of the mechanism of the reactions is possible. Although these two Reports have been prepared for publication, the information contained in them is such that it is not considered desirable, in the public interest, that they should be published at the present time. They will be released for publication at the earliest appropriate moment.

Good progress has been made at the National Physical Laboratory in the study of the stresses imposed by wind on the structure of a spirally-guided gasholder, and also in the work on the causes of noise in gas burners. This second problem is proving somewhat complex, but it has been possible to analyse, both qualitatively and quantitatively, the sounds from gas fires and from lighting and cooking burners, a step which should bring nearer their ultimate suppression. The study of the ventilation of rooms in dwelling-houses and offices has produced some interesting results, and it appears that the supposed saving to be made by constructing rooms without flues may be more than nullified by reducing the number of occupants that the room may hold, if due regard is to be paid to health and comfort. The possibilities of liquefied methane as a fuel for internal-combustion engines have been brought to the attention of the Committee, and support has been given to a study of the fundamental data now being conducted at the Imperial College of Science and Technology, London, under the direction of Professor A. C. G. Egerton.

The co-operation with the Fuel Research Board on the subject of complete gasification under pressure, has advanced considerably by the conclusion of a working arrangement for the joint provision of funds, by the Department of Scientific and Industrial Research and the Institution of Gas Engineers, for the erection and operation, at the Fuel Research Station, East Greenwich, of a semi-scale plant for the further study of the carbonisation of coal in hydrogen under pressure. Here, also, the war may lead to some delay in the prosecution of the programme, but the manufacture of the necessary plant is well in hand. Attention is drawn to the formation, during the year, of the Domestic Heating Committee, the responsibility of which is to review the whole field of domestic heat requirements and to examine the position of gaseous fuel in comparison with other fuels available for similar purposes. This work necessitates not only a comparison of thermal efficiencies and relative costs, but also covers the more difficult problems of comfort and convenience to the user. Information is being collected of experience in houses where gas is the only fuel used, and already there is evidence that with modern gas appliances an "all gas" house can be attractive to, and highly appreciated by, the occupants, while, with a suitable pricing policy, it is also low in cost.

ERNST ABBE, 1840-1905: ERRATA.—In the third paragraph of the article on Ernst Abbe, which appeared on page 66, *ante*, the name of John Dollond was incorrectly printed as "Wallond"; and in the succeeding paragraph, the name of the French glassmaker, "George Boutemps" should read "Georges Bontemps."

BRITISH STANDARD SPECIFICATIONS.

THE following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, and, unless otherwise stated, the price is 2*s.* net, or 2*s.* 2*d.* including postage.

Hand Hammers.—Prepared at the request of the Institution of Mechanical Engineers and in close co-operation with the Edge-Tool Manufacturers' Association, this specification (No. 876-39) deals with joiners', engineers', smiths', stone-breakers' and boiler-scaling hammers. The form, dimensions and weight of the hammer head are specified and requirements are included governing the quality of the material used, while practical tests on the hammers are laid down. The hammers dealt with in the specification comprise nine sizes of joiners' hammers, between 4 oz. and 20 oz. in weight; 11 sizes of engineers' ball, cross and straight-pein hammers, between ¼ lb. and 3 lb. in weight; 12 sizes of sledge hammers, double-face and cross-pein, between 1 lb. and 16 lb. in weight; six smiths' and club hammers, between 1½ lb. and 4 lb. in weight; five sizes of stonebreakers' hammers, between 1 lb. and 2 lb. in weight; three sizes of boiler-scaling hammers, respectively, 1 lb., 1¼ lb., and 1½ lb. in weight; and two pin hammers, 3½ oz. and 4 oz. in weight.

Hydrated Lime and Lime-Cement Mortar.—Two further specifications, which have been published in the BS/ARP series, relate to hydrated lime and to mortar. The hydrated lime covered in the first specification, namely, BS/ARP No. 24, is intended for use in making a cement-lime mortar for bonding brickwork and masonry, and it provides for hydrated lime produced from high-calcium quick lime or a greystone quick lime. Requirements for the chemical composition, the fineness and the soundness of the material are laid down. [Price 3*d.* post free.]

The second specification, BS/ARP No. 25, provides for a lime-cement mortar to be used in the construction of air-raid shelters in brickwork, natural or cast stone, or other structural units. The quality of the material for making the mortar, *i.e.*, the cement, lime and sand, is specified, and detailed instructions relating to four different methods of mixing which may be accepted, are laid down. These methods also include the proportions in which the materials should be mixed. [Price 3*d.* post free.]

TENDERS.

WE have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are as stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

Artesian Wells to be installed at Bouch Waterworks Station. Ministry of Public Health, Municipalities Department, Cairo, Egypt; March 5. (T. 15,041/40.)

Water-Purification Plant. The closing date for the receipt of tenders for the supply of a water-purification plant, detailed on page 718 of our last volume, has been postponed until February 6 by the Municipality of Upington, Cape Province, South Africa. (T. 29,957/39.)

Transformers, two 500 kVA, three-phase (alternatively, two 600 kVA, three-phase) and two 50 kVA, three-phase. Electricity Department, City of Cape Town, South Africa; March 6. (T. 15,056/40.)

Steel Bridgework, comprising main and cross girders, stringers and brackets bracings, bedplates, footway channels, bridge-span steelwork, stairways and trestles, and bolts and rivets. South African Railways and Harbours, Johannesburg; March 4. (T. 15,066/40.)

Rotating Disc Valves, five. Municipal Water Department, Singapore; April 18. (T. 15,145/40.)

Axles and Tyres for the North Western Railway and the Eastern Bengal Railway. Indian Stores Department, Engineering Section, New Delhi; March 7. (T. 15,336/40.)

Pipes, Valves and Fittings, with jointing material. Municipality of Robertson, Cape Province, South Africa; February 12. (T. 15,459/40.)

Pressed-Steel Tank, 20,000-gallon capacity, open-top, 20 ft. by 20 ft. by 8 ft. deep; plates to be 4 ft. square and ¼ in. thick. South African Railways and Harbours, Johannesburg; February 29. (T. 15,473/40.)

Trailer for cable hauling. Union Tender and Supplies Board, Pretoria; February 15. (T. 15,475/40.)

Airbreak Switches, six 66-kV, and four insulator posts and current-carrying parts. Public Works Department, Wellington, N.Z.; March 12. (T. 15,486/40.)

Switchgear, 11-kV, for Mataroa substation. Public Works Department, Wellington, N.Z.; March 19. (T. 15,487/40.)

PERSONAL.

MR. G. THOMSON has been appointed outdoor machinery and electrical assistant in the Chief Mechanical Engineer's and Electrical Engineer's Department, London Midland and Scottish Railway, Glasgow.

MR. M. S. MCCORQUODALE, M.P., has been appointed Parliamentary private secretary to Sir Andrew Duncan, G.B.E., President of the Board of Trade.

The section of the EXPORT LICENSING DEPARTMENT dealing with applications for licences in respect of iron and steel and foodstuffs has been transferred from 35, Old Queen-street, London, S.W.1, to Inveresk House, 346, Strand, W.C.2.

The necessary A.R.P. arrangements having been completed, the London office personnel of MESSRS. GENT AND COMPANY, LIMITED, which is now operating from 6, Draycott-avenue, Harrow, Middlesex, will be returning on February 1 to the firm's office and showrooms in London, at 147, Victoria-street, S.W.1.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The record aggregate tonnage output of iron and steel is being readily absorbed and the demand for many commodities acts as an incentive for further expansion of production. Recently, some increase of make has been possible by improvements in the supply of raw materials and still greater output is promised. Deliveries of local ironstone are larger than for a considerable time and an early further increase of supplies is likely. A new blast-furnace has been completed to produce basic iron.

Cleveland Iron.—As foundry-iron consumers continue to receive ample supplies from the Midlands, the meagre deliveries of local products are causing no inconvenience and there is still no movement towards a resumption of the regular make of Cleveland pig. Second hands hold hardly any Tees-side foundry iron, the makers' stocks of which are low. So far as can be ascertained, the efforts made to sell odd parcels of Continental products to North East Coast foundry owners have been unsuccessful, the prices asked being much above the recognised values of the output from home furnaces. Stabilised quotations for Cleveland pig remain at the equivalent of No. 3 quality at 108*s.*, delivered within the Tees-side zone.

Hematite.—Tonnage accumulations of East Coast hematite at the blast-furnaces are heavy, but the present large output is unequal to current needs, and makers are disinclined to discuss new business. They have extensive delivery obligations which they desire to reduce before entering into further commitments. Their own consuming departments are absorbing large and increasing tonnages, and buyers are not only calling for full supplies under running contracts, but are seeking to place orders ahead. Fixed prices are based on No. 1 grade of hematite at 124*s.* 6*d.*, delivered to North of England areas.

Basic Iron.—Even with the forthcoming enlargement of basic-iron supply, the whole of the present output will continue to pass promptly into direct use at the makers' adjacent steel works, and the quotation of 101*s.* 6*d.* remains nominal.

Foreign Ore.—Increased or regularised imports of foreign ore have placed consumers in a comfortable position. Stocks are better than for some time and are expected to be maintained.

Blast-Furnace Coke.—The regular deliveries of Durham blast-furnace coke are sufficient to satisfy the increasing requirements of local users. The volume of new business passing is not extensive; holders are not pressing sales and consumers are well covered. Good medium qualities are quoted at 29*s.* 2*d.* at the ovens.

Manufactured Iron and Steel.—All branches of the finished-iron and steel industry are very busily employed. Increased imports of Continental semi-finished materials and additional output of home-made semies have placed re-rollers in a position to keep the mills running at full capacity. Manufactured-iron firms have more work on hand than for a very considerable period, and producers of finished steel find it necessary to keep their plant operating at full capacity to deal with delivery demands. Government requirements are being met and the requirements of industry are receiving more attention than recently. There are ample opportunities for booking export orders at remunerative prices and producers anticipate a gradual expansion of overseas trade. Among the principal quotations for home purposes are: Soft steel billets, 8*l.* 7*s.* 6*d.*; hard steel billets, 9*l.* 10*s.*; steel ship, bridge and tank plates, 11*l.* 10*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.* 6*d.*; joists and sections, 11*l.* 10*s.*; black sheet, No. 24 gauge, 16*l.* 2*s.* 6*d.*; and galvanised corrugated sheets, No. 24 gauge, 18*l.* 12*s.* 6*d.*

Scrap.—Iron and steel scrap is becoming less scarce, owing largely to heavy imports, but all the available supplies are still promptly taken up at control prices.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—South Wales coal exporters have again been successful during the week in securing business which has been held by German shippers in the past. An order for 80,000 tons has been placed locally by the Portuguese Railways. Since August last these buyers have purchased over 190,000 tons, which represents business held by Germany during the preceding twelve months. As recently as 1936, Germany only supplied 67,405 tons to Portugal, but from that date she made strenuous efforts to gain a footing and by means of her subsidy secured orders for 332,383 tons in 1937. Owing to the considerable price advantage, Germany was able, in 1938, to displace South Wales in the railways business and secured contracts for the supply of the whole of their needs up to August of this year. In Greece, too, local shippers have made considerable headway. Since the beginning of the war, Greek buyers have been displaying a much better interest locally than has been the case for many years past, while the imposition of the Allies' blockade on German exports has made it necessary for other Greek buyers to seek fresh sources of supply. The Greek State Railways, who, twelve months ago, bought 60,000 tons of German coal, were in the local market for 25,000 tons of Welsh coal, while other Greek buyers, including some shipowning concerns, were inviting prices for the supply of about 45,000 tons. Trade with France continued along very brisk lines and it was anticipated that the French National Railways would shortly be in the market for large quantities. Inquiry generally continued along brisk lines. Offers of coal for prompt delivery, however, were almost wholely confined to a few odd cargoes. As a rule, these were easily disposed of, while stem lists, especially for the more popular sorts, were extremely difficult to negotiate for some time ahead. As a result, the general tone remained very firm.

The Iron and Steel Trade.—Active conditions ruled in the iron and steel and allied trades of South Wales and Monmouthshire throughout the past week. Works, generally, were engaged almost to full capacity in fulfilling orders already on their books and demand was still active.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—While doing a record amount of business in connection with war requirements, Sheffield industrialists are doing their best to satisfy the needs of both home and overseas commercial customers. Every effort is being made to develop those markets from which supplies from Germany have been cut off. Mr. A. J. Grant, ex-Master Cutler, states that considering the priority which has been given to home requirements, the export demand is satisfactory. British Empire requirements tend to expand. He adds that it is difficult to satisfy home requirements and at the same time find capacity to deal with export work, but it can be said that little difficulty has been caused by Government restrictions in the matter of export licences. Outputs of all types of steel are reaching record dimensions. Little difficulty has been experienced in obtaining sufficient supplies of pig iron, hematites, and scrap. High-grade steels are also in strong demand and more electric furnaces have been brought into use. One Sheffield firm has just commenced to operate three new high-frequency furnaces for the production of a wide range of special tool and die steels, including composite steel (steel-faced iron). There is a growing market in stainless steel, and heat- and acid-resisting materials. In addition, plant producing high-class cutting steels is being taxed to the limit; manganese steel is also in demand. The heavy machinery and engineering trades are operating to capacity, and the recent run on steelworks' and ironworks' machinery has been maintained. Some valuable orders have been completed during the past few weeks, including a rolling-mill plant, a cold strip mill capable of dealing with strip at a rolling speed of from 350 ft. to 700 ft. per minute, and heavy hydraulic presses. Orders are to hand for a hot strip finishing mill, a cold sheet mill, roll lathes, hot saws, hydraulic pumps, steam hammers and boilers.

South Yorkshire Coal Trade.—There has been an increased demand for house coal, and in some areas supplies are on the short side. Industrial coal is also in strong demand. Smalls are being bought in heavier tonnages by electric power stations. The coke market is active, foundry and furnace varieties being in strong request. The export position shows little change.

ACCIDENTS IN IRON-ORE MINES IN THE UNITED STATES.—From 1935 to 1937 the accident rate at iron-ore mines in the United States rose from 18·7 to 30·8 per million man-hours. In 1938, however, the rate fell to 16·7, representing a drop of almost 50 per cent. from the rate for the previous year. The improvement was general throughout the industry.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—There has been little change in the state of the Scottish steel trade during the past week, and production is being maintained on a high level. The demand for heavy material is very strong and as all consumers have so much work on hand, the pressure for deliveries is constant. The position with regard to lighter material and sheets, especially, is rather easier at the moment. While there is a fair amount of export business going through, some restriction exists because of the urgent requirements of the home market. Inquiries from overseas buyers are numerous and as supplies from Continental sources are small, some pressure is being exerted here to secure any tonnage which can be spared. Steel scrap is still somewhat scarce, but this is being remedied by fairly heavy consignments from overseas and the immediate outlook is much better. Prices are steady to firm and the following are the current quotations:—Boiler plates, 12*l.* 8*s.* per ton; ship plates, 11*l.* 10*s.* 6*d.* per ton; sections, 11*l.* 8*s.* per ton, medium plates, 13*l.* 2*s.* 6*d.* per ton; black-steel sheets, No. 24 gauge, 16*l.* 2*s.* 6*d.* per ton; and galvanised corrugated sheets, No. 24 gauge, 18*l.* 12*s.* 6*d.* per ton, all delivered at Glasgow stations.

Malleable-Iron Trade.—In the West of Scotland malleable-iron trade conditions have varied little since our last report, and producers are managing to meet all calls fairly promptly. The supply of scrap is reported to be better and prospects are satisfactory. The re-rollers of steel bars have very well-filled order books, and find difficulty in satisfying the demands of all their clients. The raw material position is better, as a considerable tonnage of semies has recently been imported. To-day's quotations are as follows:—Crown bars, 12*l.* 15*s.* per ton; re-rolled steel bars, 12*l.* 19*s.* per ton; No. 3 bars, 12*l.* 7*s.* 6*d.* per ton, and No. 4 bars, 12*l.* 12*s.* 6*d.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—The Scottish pig-iron makers are experiencing an extremely heavy demand and the pressure from the steelmakers is particularly strong. Other consumers are also calling for deliveries, with the result that the current output of hematite and basic iron is rapidly taken up. The turnover of foundry grades is fair. Prices are unchanged and are as follows:—Hematite, 6*l.* 4*s.* 6*d.* per ton, and basic iron, 5*l.* 1*s.* 6*d.* per ton, both delivered at the steelworks; foundry iron, No. 1, 5*l.* 12*s.* per ton, and No. 3, 5*l.* 9*s.* 6*d.* per ton, both on trucks at makers' yards.

DIRECTORY OF EMERGENCY ADDRESSES.—Messrs. Emergency Services (Cresco, Limited), 76, Chancery-lane, London, W.C.2, have recently published the first edition of an *Emergency Addresses Directory*, in which the present war-time addresses of business houses, industrial firms, institutions and professional persons are given. The usual address and telephone number of the organisation are quoted, and, alongside, in heavy type, appear the emergency address and new telephone number. The price of the book is 1*s.* net, or 1*s.* 2*d.* post paid.

CANADIAN MINERAL PRODUCTION IN 1939.—According to statistics furnished to the High Commissioner for Canada in London, the value of the mineral production in the Dominion is estimated to have reached 470,179,000 dols., a new high record, representing an increase of 6 per cent. over the figure for the previous year, and of 3 per cent. over that for 1937, when the previous highest total was reached. New record outputs for antimony, gold, copper, zinc, nickel, cadmium, crude petroleum, natural gas, gypsum, sulphur and lime, have been reported.

RESULT OF THE SCRAP IRON AND STEEL CAMPAIGN.—As a consequence of the scrap iron and steel canvass begun by the Iron and Steel Control some little time ago, it is estimated that about 80,000 tons of scrap metal have been recovered from various industries. A great deal of this might never have been collected but for the stimulus of the appeal. A reminder of the national need for scrap was dispatched to factory owners and industrialists all over Britain, and, beginning in London, the whole country was covered by districts and about 150,000 manufacturers were approached. The movement was supplementary to the ordinary business of the organised scrap industry. Though 80,000 tons is barely equal to the normal tonnage handled by the scrap merchants each week, it represents an extremely valuable addition to British raw-material resources. In effect, it frees about a dozen full cargoes of shipping for other essential imports. The Iron and Steel Control expects the stimulus of the campaign to persist, and it is planned to make systematic contact with other supply sources. Thus, the farmers in Gloucestershire have been approached and the results of this test survey will provide the basis for schemes to reach all sections of the agricultural community.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTE OF PETROLEUM.—To-day, 3.15 p.m., The Royal Society of Arts, 18, John-street, Adelphi, W.C.2. Presidential Address by Professor A. W. Nash.

ROYAL INSTITUTION.—To-night, 5 p.m., 21, Albemarle-street, W.1. "Long-Distance Broadcasting," by Sir Noel Ashbridge. Wednesday, January 31, 5.15 p.m., "Theory of Nuclear Forces," by Professor R. Peierls.

INSTITUTION OF AUTOMOBILE ENGINEERS.—*Sheffield Centre:* To-night, 6 p.m., The University, St. George's-square, Sheffield. "Deep Drawing Research," by Professor H. W. Swift. *Coventry Graduates' Section:* Tuesday, January 30, 7.15 p.m., The Broadgate Café, Coventry. "Hydraulic Remote Controls," by Mr. Q. H. Carlton. *Derby Graduates' Section:* Tuesday, January 30, 7.30 p.m., The Rolls-Royce Club, Osmaston-road, Derby. "The Application of Plastics to Aircraft and Automobile Construction," by Mr. O'Doherty.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—To-night, 6 p.m., The Mining Institute, Newcastle-upon-Tyne. "Propulsion Scale Effect," by Dr. W. P. A. van Lemmeren, to be read by Sir Westcott Abell. *Student Section:* Friday, February 2, 6.45 p.m., The Technical College, Sunderland. "Recent Developments in Shipbuilding and Marine Engineering," by Mr. W. Muckle.

JUNIOR INSTITUTION OF ENGINEERS.—To-night, 6.30 p.m., 39, Victoria-street, S.W.1. Informal Meeting. Lecture: "Forced Circulation Boilers," by Captain R. E. Trevithick.

INSTITUTE OF BRITISH FOUNDRYMEN.—*Scottish Branch, Falkirk Section:* To-night, 7 p.m., Temperance Café, Lint Riggs, Falkirk. "Some Principles of Cast-Iron Enamelling," by Dr. G. T. O. Martin. *East Midlands Branch:* Saturday, January 27, 2.30 p.m., The Technical College, Derby. "Cast Iron with Relation to Machine Tools," by Mr. P. A. Russell.

INSTITUTION OF MECHANICAL ENGINEERS.—*East Midlands Branch:* To-night, 7 p.m., The College of Technology, Leicester. "Cutting Tools," by Dr. G. Schlesinger.

INSTITUTION OF CIVIL ENGINEERS.—*North-Western Association:* To-night, 7.15 p.m., The Engineers' Club, Manchester. Joint Meeting with THE MANCHESTER ASSOCIATION OF ENGINEERS. "Equipment on the Manchester Ship Canal," by Mr. W. G. Smith. *Yorkshire Association:* Saturday, January 27, 2.30 p.m., The Hotel Metropole, Leeds. Joint Meeting with the *Yorkshire Branch* of THE INSTITUTION OF STRUCTURAL ENGINEERS. "Geological Faults in Yorkshire," by Professor R. G. S. Hudson.

INSTITUTION OF ELECTRICAL ENGINEERS.—*North Midland Centre:* Saturday, January 27, 2 p.m., The Hotel Metropole, Leeds. "Application of the Inverse-Time Overload Relay to the Protection of an 11-kV Network," by Messrs. J. W. Gallop and R. H. Bousfield. *Institution:* Monday, January 29, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Informal Meeting. Discussion on "Load-Building in War-Time," to be opened by Mr. F. W. Purse. *West Wales (Swansea) Sub-Centre:* Thursday, February 1, 6.30 p.m., The Technical College, Mount Pleasant, Swansea. Chairman's Address, by Mr. A. Rees. *Meter and Instrument Section:* Friday, February 2, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. "The Maintenance of Relays and Associated Equipment," by Mr. J. R. Brookman, to be presented by Mr. F. J. Lane.

INSTITUTION OF PRODUCTION ENGINEERS.—*Yorkshire Section:* Saturday, January 27, 2.30 p.m., The Hotel Metropole, Leeds. "Grinding Wheels," by Mr. A. Pearson.

ROYAL AERONAUTICAL SOCIETY.—Arrangements are being made by the Royal Aeronautical Society to resume part of the lecture programme which was postponed at the outbreak of hostilities. The giving of lectures depends upon the war situation and the censorship, but it is hoped definitely to hold four or five lectures. The first one, on "Aircraft Production", will be delivered by Mr. H. J. Pollard, F.R.Ae.S., on Tuesday, March 12, at 6 p.m., at the Institution of Electrical Engineers. Sir Alan Cobham and Mr. Marcus Langley have provisionally agreed to give a joint lecture on "Flight Refuelling in the Air." Similarly, lectures have been promised by Mr. A. A. Hall, on "Recent Theoretical and Experimental Work on Turbulence," and by Wing-Commander T. R. Cave-Browne-Cave, on "Noise and Nuisance in Aircraft," at dates to be fixed. The Wilbur Wright Lecture will be delivered at the end of May. The emergency address of the Society is:—Brook House, Old School-lane, Brockham, Surrey.

550-H.P. BATTERY LOCOMOTIVE FOR THE L.P.T.B.

(*For Description, see Page* 85.)

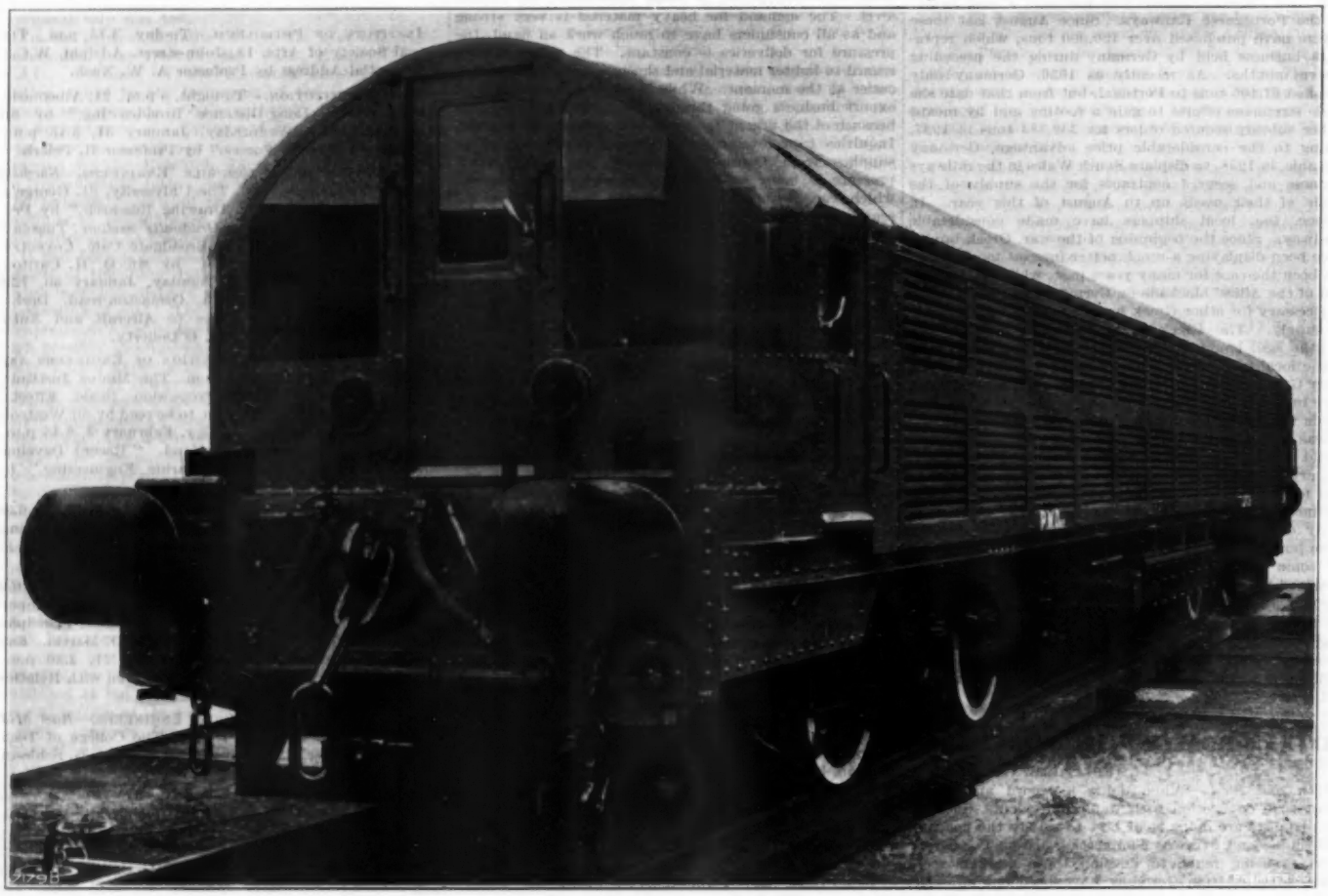


FIG. 10. END VIEW OF LOCOMOTIVE.

THE NICKEL INDUSTRY IN 1939.

EVERY year Mr. R. C. Stanley, chairman and president of The International Nickel Company of Canada, issues a review of the nickel industry, consisting of a compilation of authoritative data, submitted by the Company's technical departments, and dealing with the uses of nickel and nickel alloys in industry, particular emphasis being laid on recently-developed applications. In the review for 1939, a copy of which has recently been sent to us by The Mond Nickel Company, Limited, Thames House, Millbank, London, S.W.1, it is stated that world consumption of nickel in all its forms during the first ten months of the year totalled 92,000 tons, compared with 71,430 tons in the corresponding period of 1938 and 89,730 tons in the first ten months of 1937. It is estimated that a quantity equivalent to 60 per cent. of the output for 1939 was employed in the manufacture of steels of various types, including stainless and heat-resisting steels, 10 per cent. were used for making nickel-copper alloys and nickel-silvers, 10 per cent. entered into the production of Monel and similar alloys, and 8 per cent. were used in the electro-deposition industry. The remainder was consumed in various branches of the cast-iron, non-ferrous metal, chemical and other industries.

An important extension in the adoption of strong low-alloy corrosion-resisting steels has been observed, and it is pointed out that the majority of the steels now employed are of the nickel-copper type, containing from 0·5 per cent. to 3·5 per cent. of nickel. As rolled, these materials combine moderate cost with improved strength, a highly satisfactory response to shop fabrication, and an improved resistance to corrosion as compared with plain carbon steels. A feature of interest referred to in the review is that precipitation or age-hardening, which has long been used to improve the properties of a number of non-ferrous metal alloys, has been applied to certain constructional steels containing nickel. Hardening processes of this type have been employed in the case of structures made of nickel-copper alloy steels, which, on account of their size and complex shape, could not be treated by other methods. The final figures for stainless-steel production for 1939 are expected to exceed those for 1938, when 85,000 tons were manufactured in the United States alone. Next to constructional-steel making, the manufacture of 18-8 and other stainless steels constitutes the largest market for raw nickel. Metallurgically, the most important features have been the expanding use of additional alloying elements, such as molybdenum and columbium, and the introduction of new types, such as a "leaded" stainless, to the already successful free-machining stainless steels. During 1939 attention has been directed to the improvement of stainless steel by the addition of small quantities of silver. On account of the difficulty of introducing silver into the steel bath, the metal is usually added as an alloy containing 95 per cent. of nickel and 5 per cent. of silver.

The review states that the use of nickel in iron and steel and non-ferrous metal foundries showed substantial growth during 1939, this being partly due to increased activities at the foundries, but mainly to extensions in the uses of nickel. The alloy continues to be a fundamental addition in alloy cast irons, to control the structure and improve the properties. Nickel-iron lorry and aeroplane brake drums have been found to have a life several times longer than that of plain cast iron. In many directions, high-strength irons, made by special processes, to which nickel and other alloys are added, are increasing in popularity, and tensile strengths exceeding 31 tons per square inch have been secured. During 1939 a high-carbon, high-strength iron having non-galling characteristics and particularly suitable for lathe heads and reciprocating parts, where high pressures and wear are encountered, has been developed. Nickel-clad steel is employed in quantity in various industries, and recently the process has been extended to Monel metal and to Inconel. The latter is a stainless alloy containing approximately 80 per cent. of nickel, 13 per cent. of chromium, and 6·5 per cent. of iron. Steel plates furnished with a layer of Inconel, it is stated, are making substantial headway in connection with the construction of heavy equipment employed in the processing of fatty acids and other materials used in the soap-making industry. During 1939 the largest nickel-clad steel plates so far produced were rolled. These measured 152 in. by 151 in., and were $\frac{3}{4}$ in. thick; they each weighed 5,315 lb., and the nickel covering represented 10 per cent. of the thickness. In contrast to this achievement, seamless nickel tubing has been produced, 0·0026 in. in external diameter and weighing 1 lb. per 11 miles.

The use of heat-resisting nickel-chromium-iron alloys having a nickel content ranging from 85 per cent. to 10 per cent., and a chromium content ranging from 35 per cent. to 15 per cent., the balance being iron, is extending for annealing, heat-treating, nitriding and case-hardening equipment. It is emphasised that the part played by the nickel is that of prolonging the life of the equipment, both by increasing the strength at high temperatures and by developing a tenacious scale which is resistant to further oxidation. Light-weight boxes manufactured from Inconel sheet are stated to be replacing heavier cast carburising boxes in the case-hardening industry.

In the railway field, a recent application of a nickel alloy is in connection with the Hudd system of safety signalling. The system involves the use of large magnets, each weighing 45 lb., made from the nickel-aluminium-alloy steel Alnico and placed between the rails in the track. In the shipbuilding industry, the adoption of copper-nickel alloy tubing for ship's condensers is increasing. The Queen Elizabeth, like the Queen Mary, will have 70/30 cupro-nickel condenser tubes. The new flagship of the Holland-America Line, the liner Nieuw Amsterdam, and the United States liner America are also fitted with condenser tubes of this alloy. In the mining industry, nickel-alloy steels and cast irons are employed to withstand abrasion and corrosion, and it is of interest to note that a large Canadian gold-mining company has introduced mine cages, made of 18-8 stainless steel, and capable of hoisting 66 men.

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ENGINEERING

FRIDAY, JANUARY 26, 1940.

VOL. 149. No. 3863.

THE VICIOUS SPIRAL.

As recorded in our Labour Notes on January 5, in the first eleven months of 1939 increases aggregating 650,000*l.* took place in the wages of 3,700,000 workpeople ; in November alone, an increase of 350,000*l.* took place in the wages of 1,947,000 workpeople. These figures suggest a steeply rising curve. Covering only half the workpeople concerned, the wages increases in the last month of the eleven were more than half those of the other ten. The question of the justification for, or inevitableness of these increases need not here be discussed. The situation of which they are a symptom, however, is one to which too much attention can hardly be given. It has not been neglected in high places, and Mr. Chamberlain has made prominent reference to what he called the vicious spiral of rising wages followed by rising prices, which are then taken as a justification for further rising wages, and so on. The expression "the vicious spiral," which we think the Prime Minister was not guilty of coining, appears to have little geometrical justification—possibly a vicious helix is meant. The image which the metaphor is presumably intended to convey is a course of ever-increasing speed, leading to disaster at the end—something on the lines of a small boy out of control on a helter-skelter railway. The "vicious spiral" has, however, so quickly obtained a start in the speeches of politicians and the columns of the daily Press that it would be waste of time to try to scotch it. If it makes the public realise the conditions for which it stands, it will serve the country well.

Were memories not so short, even labour leaders might remember the little ultimate benefit that workpeople obtained from the swollen wages which were a feature of the latter stages of the last war. Prices rose both as a result of rising wages and of the shortages which were a necessary concomitant of the struggle in which we were engaged. These rising prices were met by further wage increases, and as the working classes had plenty of money to spend they were able to call for and buy articles of which there was a shortage, the consequence being that the prices went up further, the price of an article, in the absence of control, being a direct function of the demand. The country at that time appeared to act on the assumption that it had access to an inexhaustible supply of wealth, and every labour difficulty was met by further pushing up wages. This activity was particularly displayed by the politicians, and even such an able man as Mr. Winston Churchill, when Minister of Munitions, caught the fever, increasing wages in national projectile factories even before a labour demand arose. The final result of this rake's progress was the post-war slump from which, in some directions, we have not yet entirely recovered, and the full effects of which fell on the working classes. Certainly, in view of the very high wages they had been drawing over a considerable period, the workpeople should have been able to weather the slump from their own resources better than proved to be the case. The situation in which many of them found themselves showed a deplorable lack not only of foresight, but of common care.

As, particularly in the engineering industries, we have a considerably better educated proletariat than was the case during the last war, it is possible that high wages would not be squandered to the extent they were twenty-five years ago. Furthermore, the thoroughness with which the present savings campaign is being conducted should do much to encourage the husbanding of resources for a time of stringency. This saving is all to the good, but it does not meet the true conditions of the situation in which we find ourselves. In 1940, saving or no saving, we cannot afford to indulge in an orgy of continually mounting wages. No better general outline of our present situation could be given than that contained in the recent statement made to the engineering unions by Sir Alexander Ramsay, the director of the Engineering and Allied Employers' National Federation, in connection with the application for an increase of wage rates by 10*s.* a week. This would increase the wages bill of the engineering industries by 15,000,000*l.* a year.

Sir Alexander pointed out that, as a large part of the engineering industry was engaged in war work, increases in cost of production could only be met out of the financial resources of the country, or by borrowing. Taxation was the highest it had ever been in our history and was approaching the point of diminishing returns. In the last war, we borrowed 1,000 million pounds sterling from the United States. That source was no longer available and we had to rely on our own resources. These consisted of our savings at home, our investments overseas, our production for home consumption, and our export trade. Our present rate of expenditure for war purposes, which had to be met out of income and borrowing, was half the total income of the country, and the maximum rate had not yet been reached. Under such conditions, we could not carry on as *if* nothing had happened. It was the business of trade unions to try to increase the spending power of their members, but they should be sure that any course they pursued would have that result. Rising costs meant rising prices, and if wages went up, prices must follow. If domestic prices went up, the consumers must pay them ; if export prices went up, our imported foodstuffs and raw materials would cost more, and if our foreign customers did not buy at the higher prices, our situation would deteriorate still further. Rising prices would also almost inevitably affect the external value of the pound, which would further reduce our purchasing power.

Although the gravamen of this situation will probably be admitted even by secretaries of engineering unions, human nature is such that each individual is inclined to look upon his own case as an exception to the rule. While it may be admitted, in general terms, that we cannot afford to enter on a period of generally rising wages, it may quite likely be argued that, in view of the particular circumstances, an exception should be made in the case of this or that union, and that the proportion of the national expenditure for

which it is responsible is so small a part of the whole that concessions to it would not affect the general situation to an important extent. As, however, this specious argument may be advanced by everybody, it is clear that, if it is listened to, we will once more involve ourselves in a race of wages against prices. It would be well if it were frankly admitted that in the difficult period ahead we cannot maintain the standard of living to which we have become accustomed. In this connection, Sir Alexander Ramsay raised the pertinent question of our collaboration with France in armament manufacture. He pointed out that France had adopted industrial expedients which we had not yet come to, and that the standards of the French worker were much lower than the corresponding standards of this country.

This matter is of grave importance. Sir Alexander suggested that restriction on one side, and the uncontrolled conditions of 1914-18 on the other, might put a strain on economic collaboration which might affect the ultimate war issues. The importance of this consideration was well illustrated by the speeches made by Monsieur Dautry, the French Minister of Armaments, and by Mr. Burgin, on Thursday of last week, and of which we give some account on the opposite page. Mr. Burgin's forecast of a time when the manufacturing capacities of the two countries should be so united that machine tools might cross the Channel, from one side or the other, in accordance with the needs of either country, particularly accentuated the closeness of the relations which might arise between the engineering shops of the two nations. Sir Alexander Ramsay did not suggest that this country should adopt French conditions, but that we should have those conditions in mind when regulating our own procedure. It would certainly not be possible to adopt the social procedure of one country in another, at short notice. Although wages are lower in France than here, the standard of comfort is not lower. The domestic arrangements of the French family do not exhibit the extravagance which is characteristic of so many working-class homes in this country and the French workman, spending his money more wisely, gets as much for it as the English workman does for his larger sum. These considerations, however, are no reason for forcing up wages in this country and still further increasing the difference between the rates of workpeople in the two countries, who may be engaged on identical tasks and even, it appears, may operate the same machine tool.

The constitution and traditions of this country being what they are, the restriction of wages to a reasonable level in war-time will not be an easy task. One obvious method by which they can be to some extent controlled, by keeping down the cost of living, is by the institution of price controls. Something has already been done in this direction, but it is doubtful if the process offers the complete solution which the Trades Union Congress General Council appears to suppose. In this Council's report on wages and prices, it presses for the extension of rationing to the greatest possible extent, and for the "most rigid control of prices and profits." The Council also contends that wage negotiations must remain the function of the individual unions. This is not helpful. As already suggested, individuals and individual unions are apt to look at this matter purely from their own point of view. The best cure for this parochial outlook would be for the whole matter to be dealt with by some authoritative labour body. It must be remembered that a manufacturer cannot carry on his business if his selling prices are set at an uneconomic level. This is not because he is unpatriotic, but because he will go bankrupt if he tries. Already he has to face increased fuel costs, increased raw-material charges, higher taxation, heavier transport rates and many other additional burdens which necessarily increase his manufacturing costs and selling prices. If those increased selling prices are to be followed by wage rises to meet them, then we are already on the first convolutions of the vicious spiral. Anything that can be done by price control should be done, but if we fail to realise that the standards of living of peace cannot be maintained in war, then we are preparing difficulties for the future and laying the foundations for a new post-war slump.

TIMBER RESEARCH.

In normal times, the vast quantity of timber used in this country, the range of industrial purposes that it serves and the large proportion of the whole which has to be imported, are all excellent reasons for the scientific investigation of every aspect of wood and its modern products. In time of war, such research undergoes changes of effort and direction, but its value is enhanced, if anything, by the need for increased economy and an extended use of alternative grades of material consequent upon the restriction of imported supplies. The whole range of fresh problems raised by these altered circumstances can be no more than broadly surmised at the moment, but it is safe to predict that accelerated seasoning, chemical preservation, methods of machine preparation and the determination of mechanical properties will figure prominently among the economic measures adopted in timber utilisation on a national scale. Underlying the successful prosecution of all such experimental and advisory work must exist a foundation of sound knowledge, supplemented by facilities and equipment for conducting tests under controlled conditions. The Forest Products Research Laboratory, at Princes Risborough, possesses these requisites and consequently exercises a function of great and growing importance at the present time of emergency. Its full potentiality can be fully realised, however, only in so far as its services are utilised by the engineering, building and other wood-using industries.

The considerable extent to which such services are already being rendered is clearly evident from the Laboratory's latest annual Report.* Not only are the experimental results of direct value for application in structural design or works procedure, but the investigations themselves, and the methods and apparatus with which they are carried out, present numerous features of technical interest. The control of storage conditions is a case in point. It has been established that, when dry timber is to be stored for long periods, or when air-dried timber requires further seasoning, the most suitable storage condition is that which will produce and maintain a moisture content of 12 per cent. In the humid climate of Great Britain this calls for a certain amount of artificial heating, for the control of which a simple automatic device has been developed. It embodies a small block of wood mounted between contacts in the electric circuit which governs the heating supply. The contacts are adjusted so as to be just open when the moisture content of the block is 12 per cent., and so long as it remains as dry as this the wood store is unheated. As soon, however, as increasing atmospheric humidity raises the moisture content of the block, its consequent expansion closes the electrical contacts and brings the artificial-heating system into operation until the desired conditions are restored. In a small room, the results obtained with this apparatus have been remarkably good, moisture content being maintained constant within half of 1 per cent. over a period of nine months' continuous operation.

On the general question of the influence of moisture upon the properties of timber, a variety of problems are under investigation, among which particular attention is being given to the relative merits of different types and thicknesses of wood for use as new building material, and to the behaviour of valuable decorative woodwork in museums and historic buildings. The extent of the movement or "working" of structural timbers, subject to unavoidable moisture variations in service, is the subject of a detailed study from which data are being derived to enable architects to make adequate allowances in advance, so that damage to floors, panelling, and the like, may be avoided. From the preventive standpoint, concurrently, useful progress has been achieved by the examination and testing of numerous methods or preparations for pre-treating wood to reduce its susceptibility to moisture changes. Of these substances, by far the most promising is a near relation of the sugar family, known as sorbitol, which has given excellent results when applied to beech and oak. In the somewhat similar study of protective coatings for timber, an extensive series of tests on the moisture-proofing qualities of paint and varnish finishes has disclosed the remarkable fact that no such surface coating can entirely exclude moisture. Linseed oil and creosote stains, indeed, appear to be virtually useless for this purpose, while bituminous paints are found to be decidedly more effectual than oil paint or shellac varnish.

The preservation of timber from decay due to exposure to water and soil, always of deep concern to engineers, gains special interest from the recent discovery, by the Laboratory staff, of a most promising chemical treatment in which the notorious disadvantages of mercuric chloride—a most potent toxic constituent—have been almost entirely avoided by combining it with potassium dichromate and certain reducing salts such as the sulphite and nitrite of sodium. The first of these additions prevents the mercury from being leached out of impregnated wood by water or weather, while the salts prevent the corrosion of iron and steel, to the degree that the solution can be applied by pressure impregnation in steel vessels. The toxicity of mercuric chloride, in no way impaired by the other ingredients, is so high, and its fixation in wood is so permanent, as to enable the cost of the treatment to compare favourably with those of alternative wood preservatives, and to render it suitable for the protection of timber against either termites or marine borers. As regards protection against fire, recent research has established that the major action of successful fireproofing compounds is to promote the formation of charcoal, at the expense of inflammable gaseous products, when wood is decomposed by heat. Tests on Sitka spruce—a material greatly favoured by aircraft constructors on account of its high elastic modulus and torsional strength—have demonstrated that fireproofing with 20 per cent. ammonium chloride nearly doubles the production of charcoal and water due to the wood being heated at 450 deg. C., and reduces to about one-quarter the condensable organic vapours and tar.

The more positive uses of charcoal, for industrial purposes and as fuel for gas producers, are reflected in the Laboratory's studies of this material. These owe their origin to the circumstance that, while wood charcoal is serving an increasing range of commercial applications, especially in the rayon industry, this country has hitherto been largely dependent upon foreign supplies. Practical investigation has accordingly been directed to the perfection of carbonisation technique, with special reference to the manufacture, in portable steel kilns (see Engineering, vol. 148, page 89 (1939)) of high-grade charcoal containing only small percentages of volatile matter. Very encouraging results have been obtained from an experimental kiln designed to permit of temperature control, and to enable the rate of burning to be regulated automatically. Charcoal already made in this way has been pronounced, by a leading firm of rayon manufacturers, to be of equal quality to the best previously obtained from any source, while similar results are forthcoming as regards the charcoal required for the manufacture of case-hardening compounds.

The more directly engineering aspects of timber research include the systematic accumulation of data relating to the strength properties of home-grown woods, and the definition of grades of Baltic redwood to which safe working stresses can be allocated. From several hundred tests on joists of various sizes the important conclusion has been reached that the criterion of strength in such structural members is the maximum size of knot on the narrow face or edge, particularly if that edge is in tension under service loading. It appears that the weakening effect of a knot is due to the disturbance of the surrounding fibres. Hence it is immaterial whether the knot is tight and sound, loose, or decayed and removed, although it is no doubt true to say that the timber will be more efficiently used if the largest knots are on the compression edge. The size of the knot is consequently a convenient measure of the weakness due to fibre disturbance, and the opinion of the Laboratory, as

* *Report of the Forest Products Research Board for the Year* 1938. Published by H.M. Stationery Office. [Price 1*s.* 6*d.* net.]

regards Baltic redwood, is that the maximum knot diameter should only slightly exceed half the width of the tension edge for a safe working stress of 800 lb. per square inch. From the nature of this particular material, anything better than approximate numerical design data can hardly be expected, but it is significant of the variations among all types of timber that qualifying conditions govern the whole of the Laboratory's mechanical testing. Beech and Scots pine, for example, have revealed markedly different values for breaking stress and elastic modulus, according to whether the tests are conducted by centre or by four-point loading methods. Similarly, in the related field of wood bending, a working model of the lever-arm type of bending machine is being used to determine the influence of moisture content, temperature, grain direction and other factors upon the limiting radius to which wood laminations may safely be bent. The resistance of wood floors to abrasion further exemplifies the approximate nature of mechanical test results; though it is interesting to note, in this connection, that a general correspondence has been established between the density and wear resistance of flooring timbers. Also noteworthy is the similarity in wear characteristics obtained by laboratory tests and by service trials of floors laid in an underground railway station, where they are subject to intense passenger traffic. The most influential factor in resisting abrasion is the inherent quality of the wood itself, but experiment has shown that periodical treatment with oil retards the surface breakdown of floors carrying relatively light traffic.

One other aspect of the mechanical properties of timber is represented by the Laboratory's extensive study of the principles of wood-cutting, especially in relation to the design, maintenance and operating conditions of woodworking machines. On the analytical side, examination has been made of the variables in the cutting conditions, the geometry of the material and the forces imposed on the wood, from which a theoretical basis has been developed for determining the energy absorption of the machine, the resistance to feed at different rates, and the consequent effects upon the quality of finish obtained with different timbers. The conclusions thus indicated are tested practically by means of a full-sized rotary planing machine, which is provided, for experimental work, with means for altering the cutting angles of the knives, varying the speed of the spindle, and recording the feeding loads and speeds. Valuable results, offering possibilities of economy and improved production, are already available from this work, and may be expected shortly from comparable investigations relating to saw design and saw-cutting.

The foregoing examples of the Laboratory's activities, touching mainly upon the mechanical properties of timber, leave entirely out of account a large volume of work concerned with the botanical aspects of forestry, and the biological and mycological approach to problems of timber decay. Knowledge in both these subjects, primarily of use to timber growers and importers, should also concern all who use or supervise structural or decorative woodwork. The Report makes abundantly clear that the primary purpose of the Laboratory—to serve the technical industries of this country—is being fully achieved so far as the conduct of research and the accumulation of practical data are concerned. It remains for the industries to avail themselves of these proffered services. That they are already doing so is manifest from the steady growth in the number and diversity of the inquiries dealt with by the Laboratory's advisory staff. In the present circumstances, it is specially important that this and other forms of contact between research and industry should be extended and strengthened to the point of active co-operation. By such means alone can the new and urgent problems of the times be rapidly and successfully solved.

THE MINERAL INDUSTRY OF QUEBEC.—During the first 11 months of 1939, 332,080 tons of asbestos, 871,347 oz. of gold and 1,061,666 oz. of silver were produced in the Province of Quebec, against 272,347 tons, 792,466 oz. and 1,077,480 oz., respectively, in the corresponding period of 1938.

NOTES.

ANGLO-FRENCH COLLABORATION IN MUNITIONS MANUFACTURE.

THE close collaboration between the Ministry of Supply in this country and the Ministry of Armament in France was stressed by M. Raoul Dautry, the French Minister of Armament, at a Press conference on January 18. After referring to previous visits he had made to England to study railway operation in his capacity of Director-in-Chief of the French State Railways, M. Dautry spoke of the impression he had received on his present visit of the immense effort which was being made in munitions manufacture. He said it was noticeable in this country, as in France, how employers and employees were working together in the utmost harmony for the defence of the two nations. He then contrasted the position in the two countries with those which must exist in Germany, pointing out that the enormous exertions made in the latter country in armament production before the war placed her in the position of an athlete, already exhausted, starting a race with competitors who had come fresh to the post. M. Dautry then proceeded to refer to some of the ways in which co-operation in munitions manufacture between the Allies was being effected. There was no question of "negotiations" or "exchange of view" between the two supply ministries, as complete agreement existed, and the respective Ministers were purely concerned to find means of securing the most effective co-operation. It could already be said that this co-operation was even more complete than in the last month of the war of 1914-18. It was, in fact, so close that it was best expressed as union. The two departments had combined their science laboratories and their technical resources, and if and when the need arose they were in a position to combine their machine tools and labour. Although each country naturally had its own particular types of armament, at the outbreak of the war new designs were in production common to the armies of both countries. Co-operation on the technical side between England and France was further stressed in the House of Lords on January 18 by Lord Chatfield, Minister for the Co-ordination of Defence. In reply to a question, Lord Chatfield stated that mutual exchange of scientific knowledge over a wide field was concerted and already in progress between the two Governments before the outbreak of war, and we now had a complete exchange of scientific information. A direct liaison between experts on both sides had been found preferable to formal machinery, and it might be mentioned in this connection that an office in charge of M. Paul Montel had been established in the British Ministry of Supply.

RESEARCH IN WAR TIME.

In reply to a question by Lord Strabolgi, in the House of Lords last week, asking whether there was a central organisation for the examination of discoveries, inventions and improvements which might be used for the successful prosecution of the war, Lord Chatfield made a statement to which it is well attention should be drawn. In contradistinction to the position during the last war, he said, there were now no fewer than eight laboratories under the Department of Scientific and Industrial Research alone. The scientific talent of the country was now mobilised to the fullest advantage, and though there was no central organisation for dealing with inventions, this was only a small part of the scientific work that was being undertaken. Each Service Department and the Air Raids Department of the Ministry of Home Security, however, had its own organisation for dealing with inventions, and this, in practice, had been found more satisfactory than the establishment of a single organisation. There were also joint committees between the Services for dealing with such matters as radio-telegraphy, ordnance and aeronautics. Further, the scientific departments of these services, the Ministry of Supply, and the Department of Scientific and Industrial Research each year drew up plans of research to be carried out during the following year. This annual review had resulted in an enormous advance, and it also stopped work which seemed to be going on for a long time with little chance of reaching finality. There was constant consultation between the departments to prevent overlapping and, in addition, there were scientific and technical committees which covered every kind of research work. As regards collaboration with France, members of the scientific organisations of the two countries were working in British and French scientific establishments and there was a complete exchange of scientific information. An extension of this liaison, which the Government regarded as of the greatest importance, was under consideration. A Commission of Awards to Inventors would probably be created, as was done in the last war. This would constitute a very necessary safeguard of the interests of the small inventor, while at the same time securing uniformity of treatment of the more important class of inventions which involved very heavy financial commitments.

PREVENTION OF LAKE POLLUTION.

The statement in a recent issue of *The Times* that successful measures have been taken to prevent lead-mine effluent from discolouring Ullswater Lake, though perhaps primarily of importance to the land-owners of the district and to holiday makers, is not without interest to engineers. In the course of the mining process, the ore was crushed and treated and the silt from the crushing mill was then stiffened by the addition of a starch compound in soluble form. In this form, after passing through both a disc and a drum filter, it flowed into a settling tank where the sediment settled. The trouble arose from the fact that the settling process took a long time and was not completed before the tank had filled. The surplus was, therefore, being allowed to run away into a stream and thence into the lake. To overcome this difficulty, two concrete tanks, each 12 ft. by 10 ft. by 6 ft. deep, have been built against the hillside and though the results are not yet perfect, owing to the pumps and pipes having frozen, this is likely, obviously, to be only a temporary drawback. The improvement is due to Professor W. C. M. Lewis, Brunner Professor of Physical Chemistry at Liverpool University, who showed that 40 per cent. of the solid matter which entered the former settling tank passed out again into the stream. Not only did he demonstrate that the thickening agent was ineffective, but that two settling tanks, instead of the one originally proposed, were essential to satisfactory operation.

SUPPLY AREA ORGANISATIONS.

The first of the Area Advisory Committees and of the Area Boards, which are to be set up in various districts, were inaugurated in the Birmingham area on January 19. The purpose of these bodies is to assist in the development of industrial production for war purposes. The relation of the Committees to the Boards may briefly be defined by saying that the duties of the former are to advise the latter in reference to questions of output and efficient production and to assist in the survey of industrial capacity in the area. The Boards, as we understand it, will be responsible for the actual placing of orders and for ensuring that material delivered is up to specification. These different types of duty are reflected in the constitution of the two bodies. The Midland Area Advisory Committee consists of ten members representing trade unions and ten members representing employers. These latter include the chairman of the Engineering and Allied Manufacturers' Association (Birmingham, Wolverhampton and Stafford Districts) and a representative of the Federation of British Industries. The remainder are members of well-known engineering firms in the district. The Midland Area Board consists of four members respectively from the Admiralty, the Ministry of Labour, the Air Ministry, and the Ministry of Supply, together with a Secretary from the Ministry of Labour. Both bodies will deal with questions of production only and will not be concerned with labour matters. In a speech he made at the inauguration meeting, Mr. Leslie Burgin, the Minister of Supply, expressed the hope that the Committees would be instrumental in introducing new sources for the supply of war material, parti-

cularly suggesting that, with their assistance, it might be possible to place more orders among the smaller firms. Mr. Burgin stated that, in three years, the number of firms engaged directly in munition work had increased from a dozen or so to some 2,000, while 400 schemes had been approved for providing balancing plant to enable firms accustomed to peace-time production to adapt themselves to munition work. It is clear from these figures that much has been done already to extend the area of supply, but, none the less, it is certain that still further adaptations can be made. The matter is not a simple one, however, in view of the class of work and material required in armament supplies, and the constitution of these Committees, with their specialised local knowledge, should prove of great assistance in insuring that only firms capable of working to the standards required are brought into the munitions field.

PRESENTATION TO THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

It will be recalled that the outbreak of war in September last caused the cancellation of an intended joint visit of the Institutions of Civil Engineers and Mechanical Engineers to the United States, where a combined meeting was to be held with the American Societies of Civil Engineers and Mechanical Engineers. Had the visit taken place, it was intended that Mr. W. J. E. Binnie, then President of the Institution of Civil Engineers, should present to the American Society of Civil Engineers a replica of the Myddelton Cup, as a token of the friendly relations which have always existed between these two professional societies. The original cup was presented to Sir Hugh Myddelton in 1613 by the Worshipful Company of Goldsmiths of London, in acknowledgment of his services in providing London with a supply of potable water. It remained in the possession of the Myddelton family until 1922, when it was acquired by the Goldsmiths' Company. The cancellation of the visit necessarily postponed the intended presentation, but the replica was dispatched in due course to the United States, and on January 9, we have learned from the Institution of Civil Engineers, it was formally presented by Lord Lothian, the British Ambassador at Washington, on their behalf, to Colonel D. H. Sawyer, President of the American Society.

THE INSTITUTION OF MECHANICAL ENGINEERS.

IF attendance at a wholly informal luncheon be taken as a criterion, it would seem, from the presence of over 200 members of the Institution of Mechanical Engineers at such a function in London on Friday, January 19, that a revival, even if only a partial one, of the communal activities of the Institution would be generally appreciated. The President, Mr. E. Bruce Ball, in a short address of welcome, hinted, indeed, that similar gatherings might be held in the near future, and even that the normal evening meetings might be resumed. The occasion was the prelude to the delivery, at the Institution building, Storey's Gate, St. James's Park, S.W.1, of the twenty-sixth Thomas Hawksley Lecture by Sir Leonard Pearce, C.B.E., D.Sc. The lecture was entitled "A Review of Forty Years' Development in Mechanical Engineering Plant for Power Stations," and an abstract of it will be given in due course in ENGINEERING. The President occupied the chair at the meeting, the first to be held since the outbreak of war, and the proceedings commenced with the transaction of routine business. It was announced that the honorary life membership of the Institution had been conferred on Professor A. G. Christie, President of the American Society of Mechanical Engineers; Mr. Henry Ford; Major-General A. E. Davidson, C.B., D.S.O., past-president; Eng. Vice-Admiral Sir Harold A. Brown, K.C.B., G.B.E.; and Professor A. L. Mellanby, D.Sc., LL.D. The members stood for a short while in silence as a tribute to the memory of the late Eng. Vice-Admiral Sir Robert B. Dixon, K.C.B., D.Eng., whose regretted death had caused a vacancy in the list of vice-presidents. This vacancy, it was announced, had been filled by the appointment of Professor F. C. Lea, O.B.E., D.Sc., while Lt.-Col. Lord Dudley G. Gordon, D.S.O., had been co-opted as a member of Council in Professor Lea's place. The secretary then read a list of officers of the Institution who would retire by rotation at the annual general meeting to be held in February. This list consisted of:—The President, Mr. E. Bruce Ball; Vice-Presidents, Professor F. C. Lea and Mr. Asa Binns; Members of Council, Mr. Sterry B. Freeman, C.B.E., Lt.-Col. Lord Dudley G. Gordon, Major William Gregson, M.Sc., Mr. F. W. Hawksworth, Professor A. L. Mellanby, Mr. H. R. Ricardo, B.A., F.R.S., and Mr. H. W. Cadman (associate member). The Council had nominated the following members as candidates for the forthcoming election: President, Mr. Asa Binns; Vice-Presidents, Mr. Sterry B. Freeman, C.B.E., and Professor F. C. Lea; Members of Council, Mr. Cecil Bentham, Mr. C. B. Dicksee, Lord Dudley G. Gordon, Mr. J. T. Graham, Mr. A. J. Grant, Wh.Ex., Major William Gregson, Mr. A. C. Hartley, O.B.E., Mr. F. W. Hawksworth, Mr. H. R. Ricardo, Mr. A. H. Lloyd, B.Sc., Mr. Harold Sinclair, Mr. Julian S. Tritton, and Mr. B. W. Pendred (associate member). The President having announced that although, in order to ensure an election, the number of candidates was greater than the number of vacancies, it would be in order for additional names to be put forward, Eng.-Capt. A. C. Boxer, R.N., proposed Col. Sir George H. Willis, C.I.E., M.V.O. This nomination, having been seconded by Mr. S. B. Freeman, was added to the list. Sir Leonard Pearce then delivered the Thomas Hawksley Lecture. In accordance with precedent, there was no discussion. The appreciation of the members was shown, however, by the hearty manner in which a vote of thanks was accorded, on the proposition of Mr. Sidney B. Donkin, vice-president, Institution of Civil Engineers, seconded by Dr. H. L. Guy, F.R.S.

LICENCES UNDER ENEMY-OWNED BRITISH PATENTS.

To judge from the long list of applicants for licences published each week in the *Official Journal of Patents*, it would appear that the possibility of obtaining licences under enemy-owned patents from the Comptroller is of considerable interest to British manufacturers, as it certainly should be. The granting of licences is permitted by the War Emergency Act, which covers not only patents, but also trade marks, designs and copyright generally. Such licences are naturally not given away, and, in most cases, will be subject to royalties to be paid to the Custodian of Enemy Funds.

It may be asked why we should not disregard enemy-owned patents and use the inventions they cover when and how we please, without accounting to anyone for what we do. There are, however, good reasons against this somewhat piratical policy. In the first place, for what it may be worth in times such as the present, there is the ethical point of view. We have obtained details of inventions from German inventors and have granted them patent rights in return. We might, perhaps, repudiate our side of the contract for national defence purposes, but hardly for purposes of private individual gain. Furthermore, there is the question of fairness to existing British licensees under enemy-owned British patents. Clearly, these licensees, who are bound by contract to pay royalties, or make other payments or concessions, to the enemy proprietors will be placed at a disadvantage if the patents are freely used by their competitors, since such royalties have still to be paid to the Custodian of Enemy Funds. In fairness to existing British licensees under such patents, equal royalties should be paid by other persons making use of the patents. This point of view may not apply to patents in respect of which no licences have yet been granted, but in practice it would be impossible to deal differently with enemy-owned patents according as licences did or did not exist in respect of them, prior to the war.

There is also the national point of view. Patents are a form of industrial property and have an income value. They are, in fact, part of the foreign credit of the enemy country, just as much as cash, stocks and shares, house property, and so on. Just as it would be an obviously foolish policy to destroy such assets in our possession, so it would be equally foolish to ignore foreign-owned patents as income producers, and thus, in effect, destroy them. It is clearly to our interest to make the fullest possible use of enemy-owned patents to produce revenue for use in any way which may be considered expedient from the national point of view. It should not be difficult to find British manufacturers willing to pay for the right to use inventions which will improve their business in one or more of the many ways which are possible.

Moreover, apart from the possibility of patents obtained by enemy subjects having passed into British hands, or having been licensed to British firms, it must not be assumed, in the absence of any British interest in any particular patent, that it will be safe to ignore the patent in the belief that nothing can be done to enforce it. While this may be true at the present time, it must not be lost sight of that after the war, the owner of the patent may be able, if he has kept the patent in force, to sue for war-time infringement and recover damages, subject to any relief in this respect which may or may not be granted by the Treaty of Peace. Hence persons making unauthorised use of enemy-owned patents during the war might, after the war, find themselves liable to pay a considerable sum by way of damages in respect of infringement during the war years.

Although it is possible to apply for exclusive licences, it is doubtful whether these will often be granted, and doubts may sometimes arise as to whether it will be worth while to obtain non-exclusive licences. In this connection it should be remembered that a non-exclusive licensee will not be open to general competition, but only to the limited competition of other licensees, so that in effect a non-exclusive licence may be regarded, from the commercial point of view, as a minor form of patent. An important point in regard to the licences obtainable in respect of enemy-owned British patents, is that provision will almost certainly be made for the continuance of such licences after the war, so that there need be little hesitation in regard to laying down any special manufacturing plant required, or to the establishment of selling organisations. The Emergency Act offers a valuable opportunity for firms to obtain, on reasonable terms, valuable licences which they would not have been able to obtain in peace-time, but which will almost certainly continue after the war.

THE DIESEL ENGINE USERS ASSOCIATION.

(*Concluded from page* 68.)

WE continue below the report of the special meeting, held by the Diesel Engine Users Association at the Connaught Rooms, London, W.C.2, on January 11, to commemorate the jubilee of Herbert Akroyd Stuart's main patents for heavy-oil engines. The paper presented at the meeting by Mr. T. Hornbuckle and Mr. A. K. Bruce, on "Herbert Akroyd Stuart and the Development of the Heavy-Oil Engine," which we began to reprint on page 70, *ante*, is continued on page 101 of this issue of ENGINEERING.

Mr. P. C. Pope, who was apprenticed to Messrs. Richard Hornsby and Sons in 1888, said that he had seen the whole development of the firm's association with the Hornsby-Akroyd oil engine. Mr. Akroyd Stuart took a personal interest in the apprentices who were working on his engine, and did his best to explain to them the principles on which it operated. The question had been asked, why the firm did not take a greater interest in the compression-ignition, for which Akroyd Stuart had taken out a patent. He had put that question himself, at the time, to Mr. Robert Edwards, who was then their chief engineer, and had been told that the company decided to make the simpler type because they expected only small outputs and this type was cheaper to build. Also, what was now known as the compression-ignition design gave some trouble, the injection nozzle tending to carbonise and choke as the result of dribbling,

because the oil pump did not cut off sufficiently suddenly. The name of Mr. Young had been mentioned in connection with these developments, and undoubtedly he did excellent work: but there should also be a record of the good work of Mr. Gibbon, who was chief draughtsman of the oil-engine section during the initial stages.

Mr. Edwards had told him, continued Mr. Pope, that their early difficulties were really due to the fact that Akroyd Stuart, having handed over the designs to Messrs. Hornsby, did not take a very active interest in subsequent developments. He was not in good health and, had he been a stronger man, the development of the engine might have been more rapid. As showing the methods of design used in those days, Mr. Pope recalled that the choice between two flywheels of different weights was made by trying each in turn on the engine which drove the dynamo used for lighting the drawing office, and judging which was the better by observing the flicker of the carbon-filament lamps.

Major-General A. E. Davidson, C.B., D.S.O., Controller of Army Mechanisation, said that the War Department, at the end of the 19th Century, standardised two types of Akroyd engine for running search-lights in the coast-defence stations of the Empire. These were the 25-brake horse-power and 40-brake horse-power single-cylinder engines, driving electric generators by means of belts, and they stood up to their work better than the newer and faster-running types which were subsequently adopted in some stations on account of lower prime cost. In the early part of this century, the Royal Engineers purchased for the Naval authorities, for use in magazines, a number of narrow-gauge locomotives fitted with Hornsby-Akroyd horizontal engines. Three were of 9½ brake horse-power, and were delivered in 1900, 1901 and 1902, respectively; one, of 20 brake horse-power, was delivered in 1902; and one, of 75 brake horse-power, in 1904. He thought that these applications of the engine considerably antedated the Diesel locomotive. The authors had referred to the road engine which won the War Office military tractor trials in 1903, said Major-General Davidson; he was the only survivor of the War Office observers on that occasion. Messrs. Hornsby's representative was the late Mr. J. W. Young. The engine employed, variously described as of 60 brake horse-power and 70 brake horse-power, had two cylinders, one above the other, at an angle of 30 deg. Both connecting rods were attached side by side to a common crank. The engine ran at 350 r.p.m. This vehicle, in its tracked form, was undoubtedly the precursor of the many tracked vehicles possessed by our own or any other Army.

Mr. W. L. Dann thought that the Akroyd engine was really a Diesel engine, in that the fundamental point of it was used in the Diesel engine. His own early experience was mainly with the low-compression oil engine made by Messrs. Priestman Brothers, of Hull; but in the years 1891-1985 he came into contact with many other types, among them the Akroyd Stuart engines. The chief defect in them at that time was that the vaporiser carbonised very quickly under certain conditions, and the fuel nozzle often choked. The authors mentioned Akroyd Stuart engines made by Messrs. George Wailes and Company; he was under the impression that they were also made by Messrs. Weyman and Hitchcock, Limited.

Mr. O. Wans, paying a tribute to the early and fundamental pioneer work of Akroyd Stuart, thought that the modern tendency was to forget how fundamental it was. The present-day high-compression mechanical-injection engine was the direct descendant of the Akroyd Stuart engine. Those who struggled, 28 or 30 years ago, with the difficulties of introducing compression pressures of 400 lb. to 500 lb. per square inch were constantly confronted with the performance of the Diesel engine, which, it was pointed out in contemporary propaganda, had the great advantages of the constant-pressure cycle and air injection. To-day, where was the constant-pressure engine, and where was air injection? They had gone, and there remained an engine which was based fundamentally on that of Akroyd Stuart. We ought to remember that; it was a great pity that engineers of this country should have allowed an engine which was essentially a British product to be known by a German name. It could well have been called the Akroyd engine, and although the word "Diesel" had such a universal hold, he thought it was not too late for British engineers to combine and to insist on the use of the name "Akroyd." Mr. Bruce had mentioned the name of the Diesel Engine Users Association in this connection; but why should it not be altered to "The Oil Engine Users Association"?

Mr. H. Shoosmith said that he had recognised at once the portrait of Akroyd Stuart reproduced in the paper. Akroyd Stuart had been an assistant at Finsbury Technical College when the speaker was a student there; he was not a demonstrator, but was in the laboratory. In 1879, Mr. W. D. Priestman gave a lecture in Hull, in which he said that the future prime mover would be an engine working with a liquid fuel. Priestman rarely went out of Hull, and it was to be regretted that there was no record of his ripe experience and experimental knowledge.

Mr. W. A. W. Mitchell, of Newbury Grammar School, where Akroyd Stuart was formerly a student, said that a portrait of him now hung in the school buildings. He felt, after hearing the paper and discussion, that the school should try to commemorate Akroyd Stuart's work by some form of scholarship. It was a great incentive and encouragement to the younger generation to know of the work that had been done by old boys of their school. Mr. A. F. Evans, who followed, agreed with Mr. Wans regarding the credit due to Akroyd Stuart, but suggested that the invention of the Diesel engine should be attributed to the English firm of Priestman, whose patent specification he quoted in support.

Mr. T. Hornbuckle, replying to the discussion, emphasised that the authors had not belittled in any way the work done by men other than Akroyd Stuart; they appreciated that great inventions were not the work of one man, but of many. Often, however, a particular man had rendered some outstanding service that deserved commemoration, and they thought that applied to Akroyd Stuart.

THE LATE MR. H. SPENCE THOMAS.

IT is with regret that we have learnt of the death of Mr. Hubert Spence Thomas, which occurred suddenly on January 16, at Los Angeles, California, U.S.A. Mr. Spence Thomas, who had long occupied a leading position in the tin-plate industry in South Wales, was the seventh son of the late Mr. Richard Thomas, of Lydbrook, Gloucestershire, founder of the firm of Richard Thomas and Company, Limited, and was born in the Forest of Dean in 1871. He received his general education at Dulwich College, and, in 1887, at the age of 16, entered Lydbrook Tin-Plate Works as an apprentice. His training was particularly thorough, and, largely as a result of his knowledge of the practical side of tin-plate manufacture, he subsequently became associated with many of the technical developments which took place in this industry in South Wales. In 1898, Messrs. Richard Thomas having acquired the business of Morewood and Company, Mr. Spence Thomas was called to the management of the South Wales Steel and Tin-Plate Works, Llanelly. He afterwards started up the Cwmbwrla Tin-Plate Works, Swansea, and subsequently the Burry Tin-Plate Works at Llanelly. In 1907, Mr. Spence Thomas was appointed general manager of the tin-plate works of The Melingriffith Company, Limited, near Cardiff, where he remained for upwards of 20 years, and where, in collaboration with his partner, Mr. W. R. Davies, many important technical developments in manufacturing methods were introduced.

Mr. Spence Thomas continued to live in Cardiff until three years ago, when he relinquished many of his business activities and left for a world tour. At the time of his death, however, he was chairman of The Wolverhampton Steel and Iron Company, Limited, Osier Bed Works, Wolverhampton. He became a member of the Iron and Steel Institute in 1897, and after serving on the Council for some years, was recently elected an honorary vice-president. He frequently attended meetings of the Institute, and his remarks in the discussions on papers dealing with tin-plate manufacture and ancillary subjects were always of interest. He was the author of a number of contributions to the proceedings of the South Wales Institute of Engineers, of which he had been made a member in 1899. He served as President in 1925, and was elected an honorary member in 1932. Mr. Spence Thomas became a member of the Institution of Mechanical Engineers in 1925; he was also a Freeman of the City of London, a member of the Glamorgan County Council, and a Justice of the Peace for that county.

SMALL FIRMS AND WAR CONTRACTS.

WE have received from the Ministry of Supply the following notice:—Certain persons purporting to have special facilities for approaching the Ministry of Supply, and obtaining contracts, are offering their services to smaller firms particularly as intermediaries on a commission or subscription basis. The Ministry of Supply again desires, in the public interest and in the interest of these firms, to state that anyone wishing to be considered for Ministry contracts is free to apply direct to the Ministry or to the Area Officers of the Ministry, and that all such applications are dealt with on their merits. There should, therefore, be no necessity to employ intermediaries who, in return for a financial consideration, represent themselves as being able to influence contracts. The Ministry's aim is to make as full use of small firms as possible consistently with the efficiency and speed of production essential at this time in the national interest, but it is considered that small firms usually would be most useful as sub-contractors to main contractors, since it is not possible for many of the smaller firms to undertake complete manufacture of the various munitions which are required. Groups of small firms may usefully be ranged under a parent firm to form units large enough to undertake complete contracts. Several such groups of firms have, indeed, been formed.

Any groups which may be formed in the future would be required to observe similar conditions to those already laid down for the groups of firms which, in fact, have been formed to tender for woodwork contracts. The required conditions are:—

(1) That the firms who will form the group should be named;

(2) That they shall agree to allow one firm only to tender and that this firm will enter into the contractual obligations which the Ministry requires;

(3) That the firms constituting the group will provide written evidence to the Ministry that they agree to these arrangements, in particular of one firm acting on their behalf;

(4) That while the allocation of work between the constituent firms is no direct concern of the Ministry, the "parent" firm shall state on the tender form, for the purpose of inspection, the names of the firms concerned and the address of the premises at which the work will be carried out;

(5) Each of the constituent firms shall agree to the Fair Wages Clause and shall conform to the regulations applicable to the King's Roll;

(6) If any of the firms are already on the Ministry's list they shall not be invited to tender as separate units if they are within the group.

To assist firms, and particularly smaller firms not now engaged in munitions production, the Ministry some time ago arranged samples of munitions stores at convenient centres throughout the country. Officers of the Ministry are in attendance at these centres and firms wishing to inspect the stores and be advised in respect of their manufacture, are free to make appointments direct without the intervention of any intermediaries.

Sample rooms at which munitions stores may be inspected, upon application to the Area Officer concerned, are at:—King Edward House, New-street, Birmingham; Sherwood Buildings, Sherwood-street, Nottingham; 11, Piccadilly, Manchester; 32, Baldwin-street, Bristol; 141, Bath-street, Glasgow, C.2; 41, Sidney-street, Cambridge; Queen's Buildings, Queen's-street, Sheffield; 4, St. Nicholas Buildings, Newcastle-on-Tyne; and Savoy Hill House, London, W.C.2.

In addition to the sample rooms of munition stores, pattern rooms for clothing and general stores are open at addresses in London and in the chief provincial cities. Firms desiring to see samples should write in the first instance to the Ministry of Supply Area Officer at one of the addresses given, who will issue cards of admission.

BIBLIOGRAPHY ON HARDENING OF STEELS.—The Sheffield City Libraries have sent us a copy of a research bulletin containing a select bibliography of books to be found in the science and technology department of the Libraries on the hardening of steels. The bibliography deals with books on the metallurgical and general aspects of hardening, and with volumes devoted to the hardening of steels required for special articles.

LETTERS TO THE EDITOR.

PRODUCTION METHODS IN WAR-TIME.

TO THE EDITOR OF ENGINEERING.

SIR,—In the leading article in your issue of January 12, you are good enough to support my various attempts to focus attention on the deplorable fact that, even in the emergency which now confronts us, something like half the existing machine tools in the munitions industry are idle at night. I am afraid no accurate statistics are available; if they were, I believe that they would show that the position is even worse. But, on the assumption that half the machines are working at night, a simple piece of arithmetic would show that, by bringing the night shifts up to full strength, the output of munitions would be increased by one-third over the present rate of production, and this without the expenditure of any additional capital. Moreover, existing machines are complete with jigs, tools and fixtures, whereas each new machine put to work involves a considerable expenditure both of skilled labour and money in providing its necessary equipment.

In addition to the urgent need of increased production, economy in national expenditure and the provision of work for at least some of our million and a half of unemployed are of paramount importance. Millions of pounds' worth of new plant is on order, not only in this country, but in America, and while, in any event, large numbers of new machines must be installed, yet to the extent to which we make full use of the machines we have, to that extent will the expenditure on new machines be reduced. Similarly, by increasing our home output of munitions, the demand for supplies from overseas will proportionately be reduced.

While purchases in this country can be financed without undue difficulty, the question of paying for munitions and plant bought in America presents the gravest problems. American prices (at least so far as machine tools are concerned) have been raised considerably since the outbreak of war, and, in addition, dollar exchange has gone against us to the extent of something like 20 per cent. In the last war, American loans and credits were available, but these facilities no longer exist, so that the reduction of overseas purchases to the minimum becomes increasingly urgent. Our exchange position must also suffer by the curtailment of our exports, which follows from the priority which is, of necessity, given to our own requirements. If home production could be substantially increased, a larger volume of export goods could be made available. Not only would this benefit the exchange, but it would help to maintain export connections, which have been so laboriously built up and which are so difficult to restore when once interrupted.

It may be taken as a fact that little or no additional skilled labour is available, and that broad-scale dilution is inevitable, in spite of any objections that are at present raised against it. Some of my critics, as you rightly point out, have endeavoured to read into my letters a preference for the employment of women, rather than of unskilled men or youths—a criticism which is entirely unwarranted. My contention is that we must make use of *all* unemployed labour so far as we can, both men, youths and women. While dilution has been accepted in principle, yet, in attempting to apply it, many difficulties are at present encountered, and local conferences are required, which frequently prove abortive. There is still strong objection to the introduction of female labour into shops where, hitherto, it has not been customarily employed. Home Office restrictions against the employment of women and young male persons on night shifts still exist. They are excellent in times of peace, but surely the time has come for their general relaxation for the period of the war.

It is amazing that, in some circles, the present situation is considered less urgent than that which existed in the last war. But we have to face an enemy much more completely equipped, while Japan, Italy and America are neutral, instead of being allied to us. Russia, too, was an ally in the early stages of the last war, and, by diverting large masses of German troops from the Western Front, probably saved the allied armies from being overwhelmed. Now, Russia is very definitely not on our side. To me, therefore, our position appears to be decidedly less favourable, and to demand an even greater effort. Let it not be forgotten that, in addition to the men that have already been taken from industry, some two millions more are to be called up this year to join the fighting forces.

Something may be said, perhaps, on the subject of skilled labour. While no one can be more appreciative than I am of the importance of craftsmanship in the more difficult and exacting mechanical operations, yet it cannot be denied that much skilled labour is squandered on work which can quite well be accomplished by semi-skilled and unskilled labour, after very brief instruction. Mass production and repetition work provide endless opportunities for the effective employment of labour of this latter kind. When objections are raised on the score that such labour cannot usefully be employed, one is tempted to retort that the objection is probably based on the fact that it *can* do the work, rather than on any doubt as to its ability. Employers would be foolish indeed to use unskilled labour if they found it incompetent.

Additional training facilities are urgently required in technical colleges and in Government training centres, but in both institutions the aim should be to train large numbers rapidly in simple operations, rather than to endeavour to create skilled craftsmen, which is impossible except after long teaching and practice. But, most of all, it is important that individual companies should themselves institute training on a larger scale than exists at present; this is the most effective, because instruction is given on the actual jobs that have subsequently to be dealt with.

Objections are raised to the employment of women and young persons on night shifts. These objections are mainly sentimental, because most factories are blacked out and are working by artificial light, even on the day shift. Adequate supervision and welfare organisations must be provided, of course, wherever women are employed on a large scale. It may be instructive to recall the fact that in April, 1918, something like one and three-quarter million women, in addition to semi-skilled and unskilled male labour, were employed in engineering and munitions work. These figures are based on the Board of Trade Report on the Employment of Women. As soon as a sufficient number of our fighting men have been killed or disabled, we shall awake from our present apathy. But, surely, those who have vision will agree that the right course is to act now and so to reduce the dreadful toll.

You refer to another important subject: the full utilisation of smaller firms not already working on munitions contracts. War requirements are so many and so varied that in due time nearly all these firms will probably have opportunities of executing direct contracts, but the difficulties of arranging such contracts at short notice are considerable. It is probable that the firms referred to could render more effective help by undertaking sub-contracts from firms whose orders are in excess of their capacity. Skilled labour is extremely difficult to move for many and obvious reasons, and it is usually more practical to take the work to the men, rather than to bring the men to the work.

Yours faithfully,
ALFRED HERBERT.

Dunley Manor,
Whitchurch, Hants.
January 15, 1940.

TO THE EDITOR OF ENGINEERING.

SIR,—I read the leading article which appeared under the above heading in your issue of January 12, on page 39, with much interest. Provided one is prepared to grant its premises, it is logically impossible to disagree with its main conclusions, and although to quote from the context of an article may deprive the quotation of a part of its meaning, yet, nevertheless, I feel that the general conclusion is aptly summed up by the following extract:—

> "Bearing these (*i.e.*, mass production) considerations in mind, it will be obvious that the production of parts in a number of small isolated works for final assembly in another works, a method widely adopted in the last war, cannot compete effectively with continuous production, in a single works, of a product made up of a large number of components and required in large quantities. The method is practicable, but it is wasteful of man power, as the same rate of output cannot be achieved."

At this point one feels bound to ask, is this the sole consideration to be taken into account? The reason why smaller firms are grouping themselves into a Federation of Manufacturers and Producers of Great Britain is because the State economic machine is passing them by. In peace time, these manufacturers form a considerable bulk, taken altogether, of the industrial force of the nation; being small, and, therefore, adaptable, they can trim their sails and steer their courses in sympathy with the changing winds and cross currents of trade, with far greater rapidity than can the larger firms; thus they are a valuable stabilising factor in industry. They purchase their supplies of manufactured and other raw materials from the larger industrial units, and usually at higher and more profitable prices than do the larger firms.

If one were to inquire of the larger industries whether they wish to lose the volume of business placed with them by the smaller firms during peace time, there can be no doubt that their answer would be a most emphatic "No." To give employment to these smaller plants need in no way interfere with the main work of the mass-production units. Spare parts, accessories and tools of all kinds are wanted, which need never see the conveyor belt. The items can be dealt with by the Federation's own organisation under official supervision for inspection, packing and forwarding to their destinations, either at home or abroad. After all, as Sir Charles Allom pointed out at a meeting convened by Mr. J. A. R. McDonald and the Committee for the purpose of discussing this very matter, the army fights not as one solid mass, but as a large number of closely co-operating units.

When we have won this war, and then seek to reorganise our industries back on to a peace-time basis, few will deny that every five-pound note's worth of business is going to count, if we are going to avoid a repetition of the last post-war slump on a grand scale. Tariffs were introduced economically to protect the major industries, such as motor cars and steel, for instance. These did not make for lower prices to the consumer, but they enabled the industries concerned to avoid closing down, with the resultant and greater national economic loss which would have been entailed. Taken altogether, the same argument applies with equal force to the smaller manufacturers. In peace time, they are an economic asset of undisputed value; therefore, if it costs slightly more in war time to keep them at efficient strength, that slight extra cost is a profitable investment, from which one has every justification in expecting a yield of useful dividends when peace is finally declared.

Yours faithfully,
MICHAEL BENKERT.

90, Minories,
Tower Hill, London, E.C.3.
January 16, 1940.

THE BROWN-BOVERI TESTING APPARATUS FOR GEAR-WHEEL MATERIAL.

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of July 21, 1939, on page 63, you published an article on the Brown-Boveri Testing Apparatus for Gear-Wheel Material. When I sent you the article I thought that this apparatus was new. Some days ago, however, I received a doctor's thesis, entitled *Gleit-Walz-Versuche an Stahlrollen*, and published by Verlag Wilhelm Postberg, Bottrop i.W., Germany, in 1938, presented by Mr. Hans Tuschy, in 1937, to the Technical University of Danzig. In this thesis, Mr. Tuschy describes an apparatus which closely resembles the Brown-Boveri apparatus. The test results are also practically the same. I think it fair to inform you of this and should be glad also if you would kindly publish this letter.

Yours faithfully,
A. MELDAHL.

Baden, Switzerland.
January 12, 1940.

IMPROVED RESULTS FROM A PETTER SUPERSCAVENGE ENGINE.

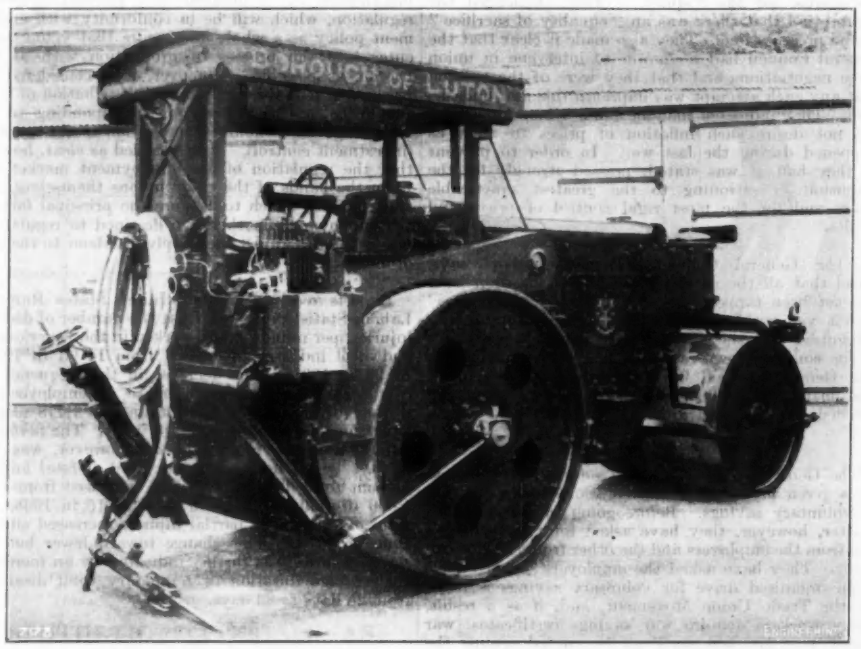
TO THE EDITOR OF ENGINEERING.

SIR,—We have read with interest Professor Davies' article on the above subject, in your issue of January 12, on page 43, and would like to make one or two comments thereon. We presume that the scavenge blower was in operation in the normal way during the tests. In order to gain some light on this point we have plotted fuel per hour against brake m.e.p. On producing the line backwards, we estimate that the friction mean pressure, indicated by the point where this line cuts the b.m.p. axis, to be about 22 lb. per square inch. In view of the remarkably good fuel consumption obtained, this figure strikes us as high for a two-stroke engine.

We have plotted the corresponding curves for the test conducted by Professor Hawkes in 1938, and it is interesting to note that they indicate a friction mean pressure of about 16 lb. per square inch, so that if this method can be regarded as legitimate, the difference of 6 lb. per square inch is due either to the difference between a two-cylinder and a four-cylinder engine, or some additional work thrown upon the engine by the application of the Kadenacy principle.

With regard to the figures plotted on the exhaust-temperature diagram, from Professor Hawkes' previous test, we feel constrained to query the legitimacy of any comparison between the two curves. It is well known that even with the same pyrometer in the same engine, wide differences in the readings can be obtained

ROAD ROLLER WITH AIR COMPRESSOR.



by varying, for instance, the depth of immersion of the thermocouple. There would no doubt be a difference between temperatures taken from two- and four-cylinder engines of identical design, due merely to the difference in the number of cylinders. These differences are, of course, due to the large heat capacity of the parts as compared with the heat content of the exhaust gases, and we feel very strongly that no comparisons should be made between exhaust-temperature readings unless taken under very carefully controlled conditions.

Yours faithfully,
BRYCE, LIMITED,
W. A. GREEN,
Development and Research Manager
(Diesel Division).

Kelvin Works,
Hackbridge, Surrey.
January 16, 1940.

ROAD ROLLER FITTED WITH AIR COMPRESSOR.

IT sometimes occurs, when a road roller is being used for scarifying, that certain places in the road surface are not accessible to the scarifier. It is necessary, therefore, to break out these areas either by hand or by a pneumatic ripper. If the areas are of any appreciable size, the latter method is naturally much more economical, but many local authorities have insufficient excavating work to justify the purchase of a portable air compressor to operate pneumatic tools. This difficulty has been overcome by the Borough of Luton by fitting a compressor to the road roller. The roller, which is illustrated in the accompanying figure, is a Marshall 9 RD-type Diesel model, and the compressor is an AT8S two-stage air-cooled machine supplied by Messrs. Holman Brothers, Limited, Camborne. The compressor is of the makers' well-known design with a differential piston and automatic plate valves. The air is drawn in through a combined silencer and air filter, and then through the low-pressure inlet valve on top of the cylinder into the first compression chamber above the piston. In this chamber, the air is compressed to about one quarter of the final pressure desired. On its upward stroke, the piston forces the air through the low-pressure discharge valve, also on top of the cylinder, to the intercooler. This can be seen in front of the compressor in the illustration. From the intercooler, the air passes through the high-pressure suction valve in the side of the cylinder into the second-stage compression chamber, consisting of the annular space formed by the difference in the two diameters of the piston. On its return stroke the piston forces the air at its final pressure through the high-pressure discharge valve, located in the side of the cylinder opposite to the high-pressure suction valve, into the receiver. The compressor is chain-driven from the take-off pulley shaft on the roller. As regards performance with the engine throttle about two-thirds open, the compressor delivers sufficient air to maintain a pressure between 80 lb. and 90 lb. per square inch with a Holman type SS11 road ripper.

THE PRODUCTION OF HELIUM IN THE UNITED STATES.

THE developments which have taken place in the last 20 years in the production of helium in the United States were referred to in a lecture delivered recently in the College of Engineering of the University of Maryland by Dr. C. W. Siebel, supervising engineer of the Government-owned helium plant near Amarillo, Texas, and also form the subject of a memorandum issued by the United States Bureau of Mines. As is well known, helium is the name given to the light non-inflammable gas used for inflating lighter-than-air craft, but, mixed with oxygen, it is also employed in the prevention and relief of "bends," an illness to which divers and workers in caissons may become liable, in the treatment of asthma, and for other purposes. It is claimed that new deep-sea diving records were made possible in 1938 through the use of helium-oxygen mixtures. The gas was discovered in the atmosphere of the sun in 1868, but it was not identified and isolated in the earth until twenty-seven years later. In 1905 helium was found to be a constituent of some of the natural gases, and this fact has placed the United States in the fortunate position, unique among the nations of the world, of possessing ample reserves of helium. In the course of his lecture, Dr. Siebel pointed out that when the United States entered the last war, in 1917, helium was a chemical curiosity which had been produced only in laboratories. Since that date, however, agencies of the United States Government have produced about 140 million cubic feet of the gas. Approximately one-third of this amount has come from a helium-producing plant near Fort Worth, Texas, which was closed in 1929, and the remainder has been produced during the period from 1929 to 1939 at the plant near Amarillo.

The present plant at Amarillo has a capacity of 24 million cub. ft. of helium of 98·2 per cent. purity per annum, but it is stated in the Bureau of Mines memorandum that, by installing another production unit in existing buildings, the output could be raised to 36 million cub. ft. per annum. As, however, the present military and commercial requirements, aggregating approximately 6 million cub. ft. a year, are met by operating the plant at about one-quarter of the installed capacity, there is a large reserve for emergencies. In addition to the Amarillo installation, the U.S. Government owns two smaller helium plants at Dexter, Kansas, and at Thatcher, Colorado; these however, are not being worked. They were built by private interests and purchased by the Government under an Act of Congress approved on September 1, 1937. To supply the Amarillo plant with helium-bearing natural gas, the Bureau of Mines has purchased all gas rights in 50,000 acres of land comprising the Cliffside gas field, which is the best source of the supply of helium-containing gas so far discovered. It is stated that, on the basis of a conservative estimate, the Cliffside area contains at least 100,000 million cub. ft. of recoverable natural gas having a helium content of 1·8 per cent. This is equivalent to a reserve of 1,800 million cub. ft. of helium, or, approximately 200 times the average annual production during the last ten years. In addition to the resources at Cliffside, the U.S. Government possesses two helium reserves in Utah, which are being retained for future needs.

THE NEWCOMEN SOCIETY.

A MEETING of the Newcomen Society was held on Wednesday, January 17, at the Institute of Indian Engineers, when two papers were read. The first was by Engineer Captain E. C. Smith, R.N., and was entitled "The First Twenty Years of Screw Propulsion, 1838-1858. Part II." Having previously given some biographical details of the principal promoters of screw propulsion, and a sketch of the work of John Ericsson in introducing the screw propeller into American vessels*, Captain Smith dealt with the early history of screw propulsion in the Royal Navy and the British Mercantile Marine, with which Francis Pettit Smith, or "Screw" Smith, as he was often called, was associated. In recalling the progress of a century ago, said Captain Smith, it was well to remember that the screw had to compete against both the paddle wheel and sail. Indeed, for a long time, the view was generally held that the screw was only a useful auxiliary, and for the commerce of the world it was considered that the most suitable type of vessel was a sailing ship with a small amount of steam power. It was these views that led to the use of devices for disconnecting, lifting or feathering screws when ships were under way. The second paper was by Mr. A. S. Davies, on "The Coalbrookdale Company and the Newcomen Engine, 1717-1769." This consisted of some extracts from the early ledgers of the Coalbrookdale Company, deposited in the Shrewsbury Reference Library in 1903, by the aid of which information can be gleaned of the cylinders which were supplied for Newcomen Engines of the period. Though, as was expected, the attendance at the meeting was small, the Society is endeavouring, as far as possible under present conditions, to maintain its normal activities, and a programme of papers for the session 1940-41 is being arranged. It was announced that the Council had elected some seventy new members, most of them resident in the United States.

THE DISPATCHING OF COMMERCIAL DOCUMENTS TO RHODESIA.—Exporters of goods to Rhodesia, via Beira, are advised to employ the air mail when sending, to consignees, documents relating to shipments of goods. It is stated in a recent issue of *The Board of Trade Journal* that invoices and bills of lading, sent by surface mail, under present conditions, frequently arrive long after the vessel carrying the consignment has discharged her cargo at Beira. This results in inconvenience and loss to the importer, and he may become liable to substantial demurrage charges.

THE ACTIVITIES OF MESSRS. C. A. PARSONS AND COMPANY, LIMITED.—Among the works carried out by, or ordered from, Messrs. C. A. Parsons and Company, Limited, Heaton Works, Newcastle-upon-Tyne, 6, during 1939 were two 50,000-kW turbo-alternators, both of which have been put into commission. One was installed in the Dunston electric power station of The North Eastern Electric Supply Company, this being the fourth machine of this output. The other 50,000-kW set is the first of two to be installed in the Bunnerong power station of the Sydney County Council, Australia. This, we are informed, is the first three-cylinder 50,000-kW, 3,000-r.p.m. turbo-alternator that has been constructed in this country. Turbo-alternators of 30,000-kW capacity have been installed in the Millfields-road generating station, Hackney; in the Littlebrook power station, Kent, and in the Mulajore power station, Calcutta, India. At the Prince of Wales power station, Rotherham, a 25,000-kW turbo-alternator was officially put into commission on March 22, while a second 25,000-kW set and a 30,000-kW set are on order for the same station. A 20,000-kW turbo-alternator has been ordered by the Commissioner for Railways, New South Wales, and the City Electric Light Company, Limited, Brisbane, has ordered a 25,000-kW machine. Many orders for smaller sets have also been received, while the transformer department has completed many important contracts during the year. The optical works of Messrs. Sir Howard Grubb, Parsons and Company, Limited, and the searchlight-mirror department have been fully engaged on work for the Admiralty and the War Office.

* See ENGINEERING, vol. 147, page 507 (1939).

LABOUR NOTES.

REPRESENTATIVES of the Shipbuilding Employers' Federation and the Confederation of Shipbuilding and Engineering Unions met in conference at the Crown and Mitre Hotel, Carlisle, on Friday last week, when the unions presented their claim for an advance of 10*s.* a week to plain time workers 21 years and over, with an equivalent advance to piece-workers. Mr. J. W. Stephenson, president of the unions' confederation, was spokesman for the trade-union side. Mr. H. Main, president of the employers' federation, in reply, said that it would be necessary to refer the case of the unions to the Central Board of the federation, for consideration, and also to the local associations of employers. The conference was then adjourned.

The latest official report of the United Pattern-makers' Association states that, in December, the number of unemployed members increased from 48 to 50, and the number in receipt of sick benefit from 200 to 238. The number of superannuated members decreased from 689 to 687. There was a net addition to the membership of 44 making the total 12,163.

The general executive council of the Transport and General Workers' Union received a report on Friday last week which referred to "serious delay" on the part of the railway companies in coming to a decision on the shopmen's claim for increased wages. In a statement for publication the council said that "this delay is causing very grave dissatisfaction among the railway shopmen of the country, and unless this state of affairs is remedied, it is likely to reflect itself in reduced efficiency within the industry. The council, therefore, calls for an immediate decision, and pledges itself to use all the resources of the union to secure a definite disposal of the wage application, believing the settlement to be long overdue."

At a meeting in London on Friday last week of the National Maritime Board, the National Union of Seamen asked the Shipping Federation and the Employers' Association of the Port of Liverpool for an increase of wages, on account of the higher cost of living, and to augment the seafarers' risk money granted last September. The union drew particular attention to the increased dangers at sea, and to the high bonuses which Scandinavian and other neutral seamen were obtaining. In reply, the shipowners referred to the danger of inflation which would be incurred if wages were governed by increases in the cost of living, and they pointed out that British shipowners were not getting the high freights obtained by neutrals. They undertook to refer the union's proposals to their constituents for consideration.

It was decided that the Ministry of Shipping should be asked to instruct their superintendents to allow war-risk money to be included when allotments are made. There was also agreement on the payment of compensation by shipowners for total loss of crews' effects by marine peril as distinct from war damage, which is compensated by the Government.

The Joint Standing Consultative Committee of the coal-mining industry resumed discussions on the question of wages at a meeting in London last week. When the miners rejected the offer of flat-rate increases of 4*d.* a shift for men and 2*d.* a shift for youths they renewed their claim for a cost-of-living sliding scale. The negotiations, it is understood, are now proceeding on that basis. Proposals related to "a formula for regulation of war additions to wages" were considered by the Committee and the miners' representatives decided to report them to their constituents.

The Minister of Labour and National Service, with the approval of the Prime Minister, has appointed Mr. F. N. Tribe to the post of deputy secretary to the Ministry, rendered vacant by the death of Mr. Humbert Wolfe. Mr. F. W. Leggett has been appointed to a new post of chief adviser to the Ministry on Industrial Relations. Mr. G. H. Ince will succeed Mr. Leggett as Under Secretary to the Ministry and will be specially concerned with National Service matters in the Ministry.

Industrial News, a publication of the Trades Union Congress, states that when he addressed the National Joint Advisory Council on the wage question, the Chancellor of the Exchequer did not ask the General Council's representatives to agree that there should be no war advances in wages. His main emphasis, it is claimed, was on the desirability, in the interests of all, of avoidance of the "vicious spiral" which occurred during the last war, when wages tried in vain to catch up with the rise in food prices. The General Council's representatives pointed out that the unions were not responsible for the "spiral." They challenged the assumption that there was an "equality of sacrifice" at the present time. They also made it clear that the General Council had no power to intervene in union wage negotiations and that they were of the opinion that any such attempt was impracticable and undesirable. They indicated that the Trade Union Movement did not desire such inflation of prices to recur as happened during the last war. In order to prevent it, they had, it was stated, pressed strongly for the extension of rationing to the greatest practicable limits and for the most rigid control of prices and profits.

"The General Council," *Industrial News* says, "feel that all the available sources of taxation have not yet been tapped and that 'equality of sacrifice' is not yet within sight. On the other hand, it is recognised that the problem of financing the war out of the country's own resources is a very difficult one. The General Council have the whole subject under examination and when definite conclusions have been reached, the affiliated unions will be advised."

The General Council of the Trades Union Congress have given preliminary consideration to the question of voluntary savings. Before going further into the matter, however, they have asked for two pledges—one from the employers and the other from the Government. They have asked the employers to agree that if an organised drive for voluntary savings is made by the Trade Union Movement, and, if as a result, many workers acquire war savings certificates, war bonds, etc., the fact shall not be quoted against the worker by employers' organisations in wage negotiations. From the Government they have asked for an undertaking that, in similar circumstances, workers who have been able to accumulate 500*l.* in this way will not be penalised by the operation of any future means test if they have to suffer a long term of unemployment after the war.

Messrs. R. A. Lister and Company, Limited, of Dursley (Glos.), have decided to pay the contributions of their workers who are on active service to the Pensions Fund and the Superannuation and Assurance Schemes in operation at Dursley. The firm will also maintain its own contributions. Steps have also been taken by the directors to provide that those in the Forces shall, as far as possible, have the benefits accruing under the funds made "applicable to their war-time risks and obligations."

The Economic Council of the Danish Labour Movement, a body set up by the trade unions and the co-operative societies, has issued a report on employment policy and prospects in Denmark. An important feature of a proposed employment plan is regulation of the employment market—that is to say, the adjustment of conditions on the employment market to general economic policy. Proposals are made for improving vocational training, particularly of unskilled workers, but these are deemed to be insufficient and the report concludes in favour of far-reaching regulation of the employment market. It makes certain concrete proposals, which, it is claimed, are based on the results of careful investigations. On the ground that it is both necessary and reasonable that the occupational distribution of labour should be subject to control, similar to that applying to the other economic factor, capital, the committee believes that rules are needed to increase the adaptability of the workers. These rules are divided into three groups: (1) Rules for controlling and regulating access to an occupation; (2) Rules for increasing the efficiency of labour, and, if necessary, facilitating the change from one occupation to another; (3) Rules for regulating migration from the countryside.

Continuing, the report states that the concrete regulation of the employment market calls for an organisation that could influence the working of the market and would be responsible for adjusting the distribution of labour to the development of industry. The activities of the organisation should be concentrated in four fields: (1) planning; (2) general information and guidance; (3) adoption and enforcement of rules to influence the composition of the working population, should the general system of guidance prove insufficient; and (4) location of new industries. It is suggested that the new central organisation should regulate the employment market and see that the interests of the trade union movement as a whole are observed.

Actually, says the report, there is already a kind of regulation, and the real problem is merely that of replacing more or less accidental and heterogeneous institutions by a uniform and planned system of regulation, which will be in conformity with employment policy as a whole and secure that young people enter into the process of production with as little friction as possible. Moreover, it is considered only reasonable that the occupational distribution of labour should be subject to control corresponding to that governing the economic contribution made by capital (investment control). It is regarded as clear, however, that the regulation of the employment market must be in the hands of the trade unions themselves. The trade unions, which to-day are the principal factor in the employment market, are destined to regulate the market and to adjust the supply of labour to the needs of industry.

Reports received by the United States Bureau of Labour Statistics indicate that the number of disabling injuries, per million hours worked in the American iron and steel industry, decreased from 14·93 in 1937 to 11·28 in 1938. This decrease in the frequency rate was accompanied by a decrease of employee-hours worked of nearly 44 per cent. in the 1,778 identical departments reporting for both years. The favourable reduction in the frequency rate, however, was offset in part by an increase in the ratio of fatal and permanent total disabilities, which increased from 11 per 1,000 disabling injuries in 1937 to 15 in 1938. The ratio of permanent partial injuries increased similarly from 65 to 82. This change toward fewer but more severe injuries was further indicated by an increase in the average duration of temporary total disabilities from 25 days to 33 days.

The Workmen's Compensation Act of Washington was held by the supreme court of that State not to be applicable to aeroplane pilots, co-pilots, stewardesses, and other employees of an air-transport company engaged in actual flying. The court declared that the extra-hazardous employments listed in the act do not include such occupations. In support of this ruling, the court discussed the history of the statute, and pointed out that when it was originally enacted in 1911 it was not applicable to aeroplane pilots and other persons engaged in flying, since transport by air at that time had not reached the commercial stage. In 1923, however, the act was amended to include aeroplane pilots and instructors. In 1937, the act was again amended, and this classification was omitted, but the classifications of aeroplane manufacturing, and teaming, lorry driving, and motor delivery were added.

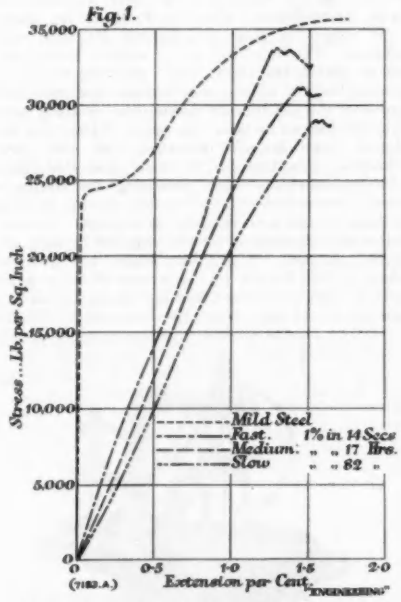
It was the opinion of the court that this omission of the classification of aeroplane pilots and instructors required a holding that such employees were no longer covered by the act, and that neither the classification of aeroplane manufacturing nor the classification of motor delivery included employees engaged solely in flying. In an Oklahoma case, compensation was granted to a pilot, but the court observed, in this connection, that the employee in that case was both a mechanic and an instructor in flying, whereas the actual case involved employees whose duties were exclusively confined to flight operations.

An unincorporated American trade union was recently held to be subject to a suit for wrongful death alleged to have been caused by an employee of the union. The Maryland Superior Court of Baltimore City ruled that such an action could be brought either against the individual members of the union or against the union as an entity, under a State statute which provides that every unincorporated association having a recognised group name may sue or be sued. It was also held that the members of an unincorporated trade union or other association are liable for the wrongful acts of an agent performed within the scope of his authority, and this even as to members having no knowledge of such acts nor directing or approving them.

The court declared that this right of action existed at common law against the individual members, but that a judgment could be satisfied only out of the common property and not out of the other property of the members. The Maryland statute "did not destroy such common-law right of action," it was said, but "the injured person has the option to sue either the members of the association, or the association itself." In this connection, the court observed that "the statute was enacted because the procedure under the common-law rule of proceeding against the members and collecting the judgment out of the common property had proved cumbersome and troublesome."

SYNTHETIC MATERIALS AS BEARINGS FOR MILLS.

Fig. 1.



SYNTHETIC MATERIALS AS BEARINGS FOR MILLS.*

By C. D. PHILIPPE.

THE laminated material used in bearings is made up of two parts, the bonding material, which is the phenol-formaldehyde resinoid, and the filler, which, in this case, is a woven cotton cloth. The cotton cloth is treated with the resinoid and many layers are consolidated into a solid mass under heat and pressure. The material is now hard, infusible, insoluble, stable and very non-hygroscopic, although it does absorb a very small percentage of water on its surface only. Obviously from its formation, the material is heterogeneous and non-isotropic. The chemical change which has taken place during the moulding operation being irreversible, the material is not allotropous. Its specific gravity is 1·35. It fills the gap between wood and the light metal alloys. The tensile strength across the face in two directions is between 4 tons and 5 tons per square inch, and through the thickness of the board is about 2 tons per square inch. The tensile strength can be partly controlled by the arrangement of the reinforcing fibres, and, if desired, considerably higher strength can be obtained in one particular direction. Its shear strength through the laminations is between 4 tons and 5 tons per square inch, while its compressive strength flatwise is somewhere near 18 tons on a 1-in. cube. Table I gives comparative values for metal alloys, plastics and wood.

TABLE I.

Material.	Tensile Strength.	Compressive Strength.
	Lb. per sq. in.	Lb. per sq. in.
Stainless steel (18-8)	185,000	150,000*
Aluminium alloy (24-ST) ..	62,000	40,000*
Magnesium alloy (A.M.585) ..	46,000	35,000†
Phenolic resin. Cord filler ..	27,000‡	27,000
„ „ Paper filler ..	21,000	30,000
„ „ Fabric filler ..	14,000	40,000
Aircraft spruce (Douglas fir) ..	10,000‡	5,000

* Yield point in compression.
† Yield point in tension.
‡ In one direction only.

In many cases strength alone is not the most important factor, and when judged on a strength per unit weight ratio basis synthetic resin materials, as shown in Table II, compare favourably with other materials.

The Brinell hardness, using a load of 125 kg. on a 5-mm. ball, gives a reading between 33 and 37. It is difficult to assess a true hardness value, as the impression of the ball may be taken in a variety of positions relative to the weave of the filler, and this gives rise to large variations in the results obtained. The Brinell hardness, as far as it is yet known, is not considered a criterion of the properties required for bearings. The thermal conductivity is very poor, and the material can almost be classed as a heat insulator. Its coefficient of thermal expansion differs along the laminæ and through the laminæ; through the laminæ it is 0·00006 in. to 0·00008 in. per in. per deg. C., while along the laminæ it is 0·00003 in. to 0·00004 in. per in. per deg. C. The figures given do not cover all grades of phenolic laminated material. In other grades strengths up to 15 tons per square inch can be obtained, accompanied by changes in other properties. In the case of metals it is known that there is a definite relationship between tensile strength and shear, but no such relation has as yet been established in the case of synthetic resin materials. The modulus of elasticity differs in tension and compression, and the material has a very pronounced hysteresis loop under stress, with a very slow time recovery. The stress-strain curve lacks the well-defined yield point of metals, and does not appear to follow Hooke's law, deviating from a true elastic curve almost at the origin, but maintaining a firm curve right up to the breaking point. Different values of E are obtained by different rates of loading. Fig. 1, on this page, shows typical curves for a paper-base material.

* Paper read before the Midland Metallurgical Society, in Birmingham, on November 30, 1939. Abridged.

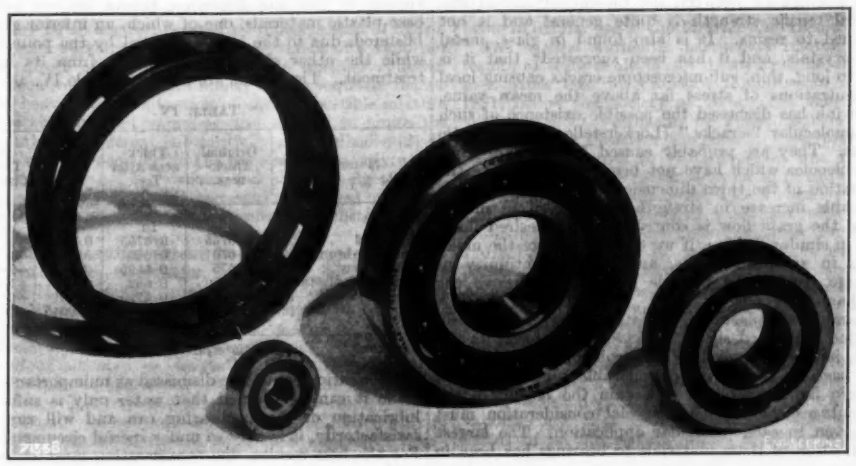


FIG. 2.

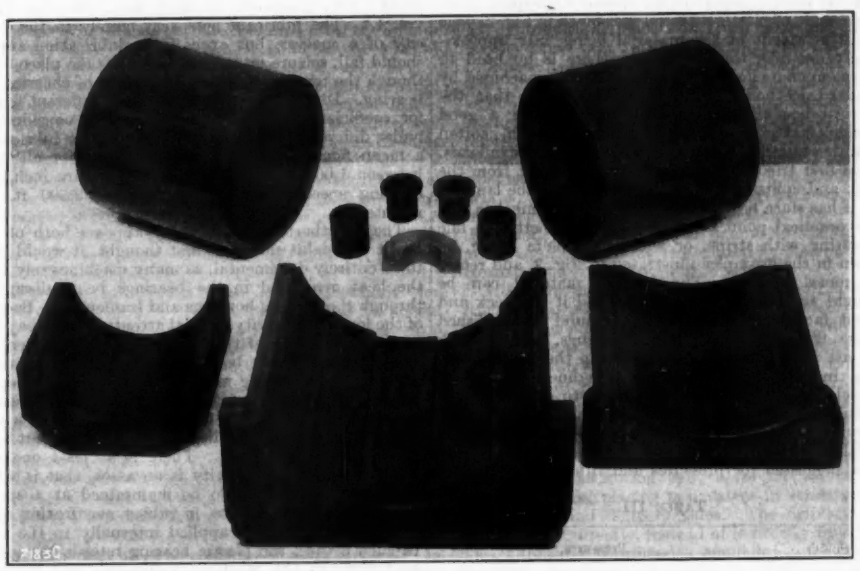


FIG. 3.

TABLE II.

Material.	Tensile Strength. / Sp. Gr.	Compressive Strength. / Sp. Gr.
	Lb. per sq. in.	Lb. per sq. in.
Stainless steel	23,600	19,100
Aluminium alloy	22,100	14,300
Magnesium alloy	25,400	19,300
Aircraft spruce	23,300	11,600
Phenolic resin. Fabric filler ..	10,400	29,000
„ „ Paper filler ..	15,600	22,000
„ „ Cord filler ..	20,000	20,000

With the scanty information at present available, no account can be given of its plastic or elastic deformation under stress. It has considerable power of recovery, which is greatly accelerated by gently heating the specimen. The material has a high degree of resistance to chemical attack, and is unaffected by dilute acids or alkalies. It is slightly attacked by strong caustic soda and pure alcohol, but is impervious to all weather conditions.

Phenolic resinoid material is not allotropic, as prolonged heat or intense cold will not change its physical properties once it has reached the final hardened stage. The reaction between phenol and formaldehyde has not yet been completely elucidated. From X-ray analysis, it has been deduced that the phenol-formaldehyde resin is a completely amorphous material and appears to be just a confused pattern of macro molecules; it has no definite arrangement or regular plan, such as is found in natural materials, or even in the dendritic forms which are produced during the process of crystallisation in metals. There have been numerous investigations* which point to this amorphous material being an "isogel," held together by two kinds of bonds: (1) the primary chemical bonds holding the molecules together, and (2) secondary bonds called Van der Waal's forces, which are cohesive forces which can hold molecules together where there is no actual chemical combination. J. H. de Boer† has shown that a large discrepancy

* R. Houwink, *Physikalische Eigenschaften und Feinban von Natur-und Kunstharzen*, Leipzig, 1934. Also *Journ. Soc. Chem. Ind.*, vol. 60, page 247 (1936).

† *Trans. Faraday Soc.*, 32, Jan., 1936.

exists between the theoretical tensile strength calculated on primary or secondary bonds only and the experimental figures obtained. In practice, we only get some 0·5 per cent. of the theoretical strength. This discrepancy between the theoretical and experimental tensile strength is quite general and is not confined to resins. It is also found in glass, metal and crystals, and it has been suggested* that it is due to long, thin, sub-microscopic cracks causing local concentrations of stress far above the mean value. Houwink has discussed the possible existence of such intramolecular "cracks" (Lockerstellen) in synthetic resins. They are probably caused by the loose ends of molecules which have not been tied up during the formation of the three dimensional structure. A considerable increase in strength is observed in metals when the grain flow is controlled along desired lines, and in similar fashion, if we could orientate the molecules in synthetic resins, and ensure continuity of linkage, we should be able greatly to improve the mechanical properties.

Laminated plastics, or rather "synthetic resin bonded laminated sheet" to give the material its full title, has been applied to the problem of bearings for the past 10 years with considerable success. It has certain limitations, and to obtain the benefit of the advantages that it offers, special consideration must be given to each particular application. The largest application of these materials to bearings has been in rolling-mill plant, although much success has been achieved in other spheres. They have found their way into ball and roller bearings where the cages are made of plastic materials for special high-speed jobs. Cages made of plastic material are shown in Fig. 2, page 99. The weight of the material being only approximately one-fifth that of metals, there is no need to enlarge upon its lightness. It can be easily machined by standard methods. Experience has shown that the material has all the strength necessary for a good bearing material. It does not age-harden, soften under heat, or flow to any extent under excessive loads. When first tried, complete bearings were cut from the solid, and splitting was experienced along the laminæ, but it has since been found, from an economical as well as a practical point of view, that it is better to line a bearing with strips, or with a complete lining, as shown in the examples illustrated in Fig. 3, and retain the metal housing. The bearing material can be brought to a high surface finish, and if the neck and thrust faces of the journal are ground and polished before fitting synthetic resin bearings, the bearings will act as a polishing pad and keep the bearing surfaces in good condition. Any roughness or surface irregularities on a journal are likely to cause a considerable amount of wear in the bearing. The load-carrying capacity is generally higher than that of metals. The subdivisions given in Table III have been suggested for pressures and rubbing speeds.

TABLE III.

Loads.	Pressures.
Light	Up to 500 lb. per square inch.
Medium	From 500 lb. to 1,500 lb. per square inch.
Extra heavy ..	Over 4,000 lb. per square inch.
Rubbing Speed with Water as Lubricant.	
Light loads ..	100 ft. to 4,000 ft. per minute.
Medium loads ..	150 ft. to 3,000 ft. per minute.
Heavy loads ..	250 ft. to 2,500 ft. per minute.
Extra heavy loads	Require grease or sud-oil with water.

Not only is the material capable of maintaining these high loads, but the machine may also be stopped and restarted under load without fear of seizure or scoring of the journal. In one particular application, a cold-rolling mill for stainless steel, it was found that narrower limits of the rolled strip could be maintained, and if variation did occur, the machine could be stopped, adjusted and restarted without trouble. If this procedure had been attempted prior to the introduction of plastic bearings, the machine would have been almost torn from its foundations and heavy scoring of the journal would have occurred. The lubrication of the plastic bearing was by a water-soluble oil forced under pressure through the bearing on to the journal. While rolling the biggest step, the pressure in the journal neck was estimated at over 5,000 lb. per square inch, the strips produced being 0·008 in. thick, to limits of ± 0·0001 in.

Because of the high resistance to impact, creeping or flowing, such as occurs in Babbitt and other bearings under the hammer action of work entering the rolls, does not take place with phenolic laminated bearings. An empirical test carried out shows up this property well. Several pieces of different material—2 in. square by 0·675 in. thick—were placed on a solid floor. A flat-nosed tool was fitted to a pneumatic road drill and the squares pounded in turn for three-quarters of a minute. All the specimens showed a considerable amount of flow and distortion, except the two fabric-base plastic materials, one of which, an inferior grade, blistered, due to the heat generated by the pounding, while the other showed no ill-effects from its harsh treatment. The results are shown in Table IV.

TABLE IV.

Material.	Original Thickness.	Thickness After Test.	Diff.	Per Cent. Change.
		In.	In.	
Mild steel	0·6765	0·6755	0·001	−0·148
Phosphor-bronze ..	0·676	0·666	0·010	−1·480
Naval brass	0·675	0·6595	0·0155	−2·295
Laminated plastic (1)	0·675	0·682	0·007	+1·035*
" " (2)	0·6715	0·6725	0·001	+0·149
" " (3)	—	0·6730	0·0015	+0·223

* Material blistered.

Lubrication cannot be dismissed as unimportant, for, while it can be claimed that water only is sufficient lubrication or that a bearing can and will run dry satisfactorily, it is only so under special circumstances. For the best results, due consideration must be given to the question of lubrication, and the various questions involved are discussed in several papers included in "The General Discussion on Lubrication and Lubricants," *Proceedings of Inst. Mech. Eng.*, October, 1937, vol. I.* The lubricant acts very largely in the capacity of a coolant, but even if the lubrication supply should fail, seizure or scoring does not take place, even though the temperature rises to a point of charring the bearing. Different investigators quote different figures for coefficients of friction, which varies considerably under different conditions, but using water lubrication a mean figure of 0·0035 may be taken for all loads between 1,000 lb. and 4,000 lb. per square inch, and rubbing speeds between 500 ft. and 3,500 ft. per minute.

The low thermal conductivity appears both on the credit and debit side. At first thought, it would seem to be entirely detrimental, as many machines rely upon the heat generated in the bearings being dissipated through the bearing housings and framework. Because of the low conductivity, special attention must be given to the elimination of the heat of friction, particularly where the rolls must be kept at an even temperature, such as in cold-rolling mills. This cooling is generally performed by the lubricant, although in some cases a plastic bush is fitted in the journal and rotates with the roller, so acting as an insulator to prevent heat being passed to the roll body. There is at least one case where the low conductivity is an asset, that is where the rolls are required to be maintained at a special temperature, for instance, in rubber masticating mills, where heat has to be applied internally to the rolls. In such a case, the plastic bearing retards the loss of heat through the machine framework and improves the general efficiency. The coefficient of friction is small and is constant for widely varying speeds. This behaviour is attributed to the low elastic modulus of the material. Any tendency for high pressures to concentrate at certain points and so destroy the lubricating film is lessened by the appreciable deflection or compression of the bearing lining, which takes up the pressure in such a way that the lubricating film does not decrease in thickness as much as it would do with a rigid bearing under the same total loading. The result is a more even distribution of pressure and hence a more uniform thickness of lubricating film. The so-called hard-wearing properties of the material may be due to its ability to hold on its surface a much heavier film of water than metal, since there is not only surface tension, but also the affinity of the cellulose filler for water. Several reports† have shown that once confidence has been established with the new bearing materials, heavier loading and greater output could be obtained, while a saving of 25 per cent. to 30 per cent. in the power consumption was not uncommon. With water only used as a lubricant a longer life is obtained, the shut down periods are less frequent and maintenance costs much less. There are several limitations which must be taken into consideration. The poor heat conductivity necessitates an adequate supply of cooling media; with standard cotton filled materials, this must be sufficient to maintain the temperature on the bearing surface below 300 deg. F. Newer materials have shown that an operating temperature of 750 deg. F. may be possible, but they have not yet been tested for such applications as bearings.

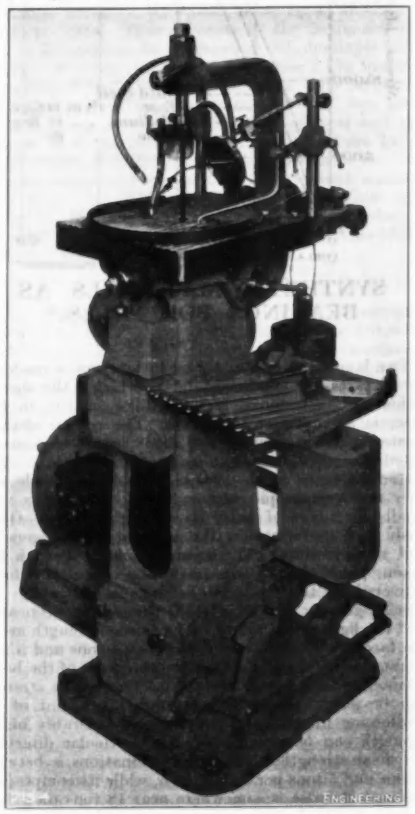
* A. A. Griffith, *Phil. Trans. Roy. Soc.*, A. 221, page 163 (1920).

* See ENGINEERING, vol. 146, page 553 (1937).

† No. 136 German Iron Masters Rolling Mill Committee, *I.P.I. Trans.*, 1936-37, vol. 6, No. 11, page 64.

JIG-SAWING AND FILING MACHINE.

THE new jig-sawing and filing machine shown in the accompanying illustration has been recently introduced by Messrs. Edward G. Herbert, Limited, Atlas Works, Levenshulme, Manchester, 19, as an addition to the range of their well-known Rapidor sawing machines. The machine is, of course, intended for work on metal, the term "jig" referring to the reciprocating action of the saw or file, and not to the purpose of the machine in making the centring devices commonly known as jigs. Machines of this type have, hitherto, been largely imported, but this British production embodies all the really desirable features of foreign machines while retaining the simple and robust construction of the Rapidor sawing machines. The base of the new machine is a single box-section column with extensions for carrying the driving motor and its gearbox. The table, which has a working surface 15 in. by 15 in., is mounted on a pivoted cradle, so that it may be tilted in four directions to any angle up to 15 deg. from the horizontal. Effective



locking gear is provided. The tilting adjustment enables such work as pierced dies with clearance to be readily carried out.

The saw frame is particularly stiff and is of Tee-cross-section. It is guided by a slide bar 1½ in. square, made of 45-ton carbon steel and working on extra long bearings. The stroke is adjustable from zero to 4 in., and as four rates of working, viz., 222 strokes, 145 strokes, 111 strokes and 72·5 strokes per minute, are available, the range of cutting speeds afforded by the combination of number and length of stroke is considerable. The capacity is indicated by the facts that work up to 3 in. thick, either for sawing or filing, can be accommodated, and that the distance between the back of the saw or file and the saw frame is 9 in. The machine is normally supplied for operating on alternating current, a four-speed motor being fitted. Transmission is through a worm gearbox in which the gears run in oil. Starting and stopping is by push-button and the gear is controlled by the pedal seen to the right of the base.

The equipment comprises a pair of work hold-downs carried on vertical arms and adjustable both vertically and horizontally; adjustable fittings for an electric lamp and mirror reflector; an air blower and chute for swarf and dust; and a weight-operated gravity feeding attachment. Other equipment includes a magazine for coil saw blades, holders for straight hack-saw blades, and for standard files. The saw frame is fitted with attachments for the easy interchange of saw blades and files. It may be noted that hardened and ground shafts and crankpins with phosphor-bronze bearings are employed throughout. All working parts, except the oil bath gearbox, are fitted with grease-gun lubrication.

HERBERT AKROYD STUART AND THE HEAVY-OIL ENGINE.*

By T. HORNBUCKLE, B.Sc., A.M.Inst.C.E., and A. K. BRUCE, M.I.Mech.E.

(*Concluded from page* 71.)

PROFESSOR ROBINSON, whose advice and encouragement were of high value to Akroyd Stuart, confirmed some of the particulars relating to the testing of the first engines built in the light of experience obtained with the experimental petrol engine. While the vaporiser was, for the initial start, heated by an external flame, as soon as its temperature was high enough to ensure (with the additional heat given by the compression) automatic ignition, the external flame was no longer necessary, and the engine went on running with automatic ignition and timed injection. Although the final ignition temperature was obtained by compression, a large proportion of the heat was obtained by radiation and conduction from the vaporiser, a proportion which, of course, varied with the load. Some improvement being necessary in order to obtain dependable ignition and good combustion over a wide range of speeds and loads, an improved type of vaporiser was evolved. Instead of drawing air into the vaporiser, air was drawn into the cylinder and thereafter forced into the vaporiser through a contracted neck, the fuel oil being injected directly into the vaporiser. This new arrangement was a marked improvement and, incidentally, it allowed the fuel to be injected during the induction stroke without danger of pre-ignition.

The next step in development was a vaporiser with the neck and other parts water-jacketed. The object of this modification appears to have been two-fold: the raising of the compression pressure to enable heavier fuel oils to be burned, and the prolongation of the life of the vaporiser by reducing the liability to fracture at the neck. Professor Robinson stressed the extreme importance of this improvement as the means whereby the compression pressure could be raised, heavier fuels burned and the thermal efficiency improved. It should be mentioned, however, that in attributing to Akroyd Stuart the invention of the water-jacketed vaporiser, Professor Robinson cannot have known of the existence of C. W. Pinkney's patent No. 103 of 1891, applied for on January 2, 1891. Since Pinkney's complete specification was not accepted until December 5, 1891, we need not doubt that Akroyd Stuart himself was unaware of the prior publication.

The water-jacketing of the vaporiser was followed by a further modification designed to enable heavier and more viscous oils to be burned. The vaporiser was divided into two sections: a pilot charge of lighter oil was injected into the first section during the induction stroke, while the heavier oil was injected into the second section at the end of the compression stroke. Although this arrangement does not appear to have been put into practice at the time, it is the first example which we have found of pilot ignition.

It will now be appropriate to describe the contents of Akroyd Stuart's patent specifications Nos. 7146 and 15994, both of which were applied for in 1890. These are the patents covering, respectively, the automatic-ignition engine with injection at the end of compression, and the engine subsequently built by Messrs. Richard Hornsby and Sons as the Hornsby-Akroyd engine.

In the provisional specification of patent No. 7146 it is declared that the "inventors have given the novel means by which we are able to keep the vaporiser at an intense heat and yet prevent the pre-ignition of the explosive mixture, which if produced and drawn into the cylinder in the ordinary manner would explode on some part of the compression stroke of the cycle and stop the engine." The provisional specification goes on to declare that "the induction stroke which is the first outward stroke instead of drawing into the cylinder a mixture of hydrocarbon vapour and air, simply draws in pure atmospheric air; the compression or first return stroke, compressing this air into the intensely heated vaporiser, and at the desired part of this compression stroke, the supply of liquid hydrocarbon is forced, in a spray form, on to the heated vaporiser, which almost instantly changes it into a gas, it combines with the heated air; automatic ignition takes place, and propels the piston which forms the working or second outward stroke. The return stroke of the piston clears the products of combustion from the cylinder and so on." In the complete specification the wording used is: "In order to prevent the pre-ignition of the explosive mixture, owing to the high heat of the vaporiser, we first compress the requisite supply of air for the charge and then inject the oil into this compressed charge by the use of a pump or the like, the injection of the oil being correctly timed to correspond with the position of the piston at the time the explosion is to take place."

The complete specification of patent No. 7146 is dated November 5, 1890, and contains five claims. The significant ones (the first and second) are as follow: "(1) In an engine operated by the explosion of hydrocarbon vapour and air, the employment of a vaporiser in direct communication with the working cylinder, which vaporiser is maintained at the requisite degree of heat by the combustion of the combustible mixture therein, the said vaporiser also serving to ignite the combustible charge, substantially as described. (2) In an engine operated by the explosion of a mixture of combustible gas or vapour and air, forming the said mixture by introducing the combustible gas or vapour into a charge of air under compression, substantially as described."

Application for patent No. 15994 was entered six months after application had been made for patent No. 7146. In the provisional specification of patent No. 15994 it is stated that "the chief object of our present invention is to provide means, whereby the necessary quantities of combustible vapour or gas and of air may be drawn in during the suction or outstroke of the piston, notwithstanding that a permanent igniter is employed, without liability of pre-ignition." In the complete specification (dated July 8, 1891) this chief object is further expanded thus: "The chief object of our present invention is to provide means whereby the necessary quantities of combustible vapour or gas and of air may be drawn in during the suction or outstroke of the piston, when a permanent igniter is employed, without liability of pre-ignition, and for this purpose, we attach to one end of the cylinder an explosion chamber (which chamber in a liquid hydrocarbon engine also serves as a vaporiser) of sufficient capacity to contain the combustible charge; the opening or passage which establishes communication between the cylinder and the explosion chamber being contracted in area, that is to say, of much less diameter or area than the cylinder or the explosion chamber in transverse section; and we form the inlet for the air in the walls of the cylinder and that for the hydrocarbon liquid or other combustible vapour or gas in the walls of the explosion chamber, so that air can only enter the explosion chamber from the cylinder, through the contracted passage."

The complete specifications for both patents were drawn up by Messrs. Redfern and Company, in consultation with Lord Moulton (then Mr. Fletcher Moulton, Q.C.). This course appears to have been recommended by the patent agents in order to avoid confusion between the two patents. Professor Robinson stated that all Akroyd Stuart patents, from 1886 onwards, were examined, and that the provisional specifications were studied separately and together. It was decided that the final specification of patent No. 7146 should be completed without delay and that the vaporiser with contracted neck should be described therein but disclaimed in connection with this patent in order to reclaim it in the final specification for patent No. 15994. The disclaimer was made in the following terms: "As, however, the construction of the vaporiser forms part of the subject matter of patent No. 15994 dated the 8th of October, 1890, no claim thereto is made in this specification."

Apparently the intention was to cover the cycle of working in the first patent, and the combustion chamber and alternative method of working in the second patent. This appears to be confirmed by the following statement made to the patentees: "Nevertheless, in the future if you desire to do so, you will be at liberty to use that or any other construction of combustion chamber or vaporiser with Akroyd engines working according to your patent No. 7146 of 1890. The engine cycle is your invention and we point this out for your guidance. This method of procedure will protect your patent rights." Unfortunately, this method of procedure—adopted for legal considerations—has caused confusion by suggesting that the combustion chamber with contracted neck was intended for use solely on engines working in accordance with patent No. 15994, and that the original type of combustion chamber was retained on engines working in accordance with patent No. 7146.

In the list of Akroyd Stuart's more important British patents it will be noted that, while the first was applied for by Akroyd Stuart himself, the second and third patents are in the joint names of Charles Richard Binney and Herbert Akroyd Stuart. The fourth patent in the list (the patent relating to the automatic ignition engine with timed injection) was applied for by Herbert Akroyd Stuart and Charles Richard Binney, and this sequence of the names is found in all the subsequent oil-engine patents. Mr. Charles Richard Binney was not concerned in the actual inventions as such, his interest being financial.

Akroyd Stuart built his earliest engines at his works at Bletchley. In addition, he had engines built for him by Messrs. G. Wailes and Company, Euston-road, London, whose then existing workshops had been established about 1790, when this part of Euston-road was known as Palace-row. During the Nineteenth Century important engineering work was carried out here for scientific pioneers such as Siemens and Ferranti. Early in 1891 about a dozen engines had been manufactured in sizes varying from 1 h.p. to 6 h.p., a number being in regular use at the Bletchley Works.

The earliest authentic particulars relating to the results of tests made on an Akroyd engine are found in a paper read by Professor Robinson on April 29, 1891, before the Society of Arts. The subject was: "The Uses of Petroleum in Prime Movers"; the chairman was Professor Silvanus P. Thompson; and among contributors to the discussion was Professor W. C. Unwin. The engine referred to in the tests had a cylinder 9½ in. in diameter, with a stroke of 16 in., and the indicator diagrams (obtained with a very unsatisfactory indicator) appear to show an average I.M.E.P. of about 36 lb. per square inch, with compression pressure of from 30 lb. to 35 lb. per square inch. At a speed of 216 r.p.m., the output was approximately 7·6 brake horse-power, and the consumption is given by Professor Robinson as 0·9 pint per brake horse-power hour. The fuel-injection arrangements were extremely crude both in design and manufacture, the fuel-pump plunger having a diameter of ½ in., with a stroke of rather less than ⅝ in. An interesting point is that the vaporiser (at that time unjacketed) was cooled by means of an air current which could be controlled. Notwithstanding the improvised and inexact fuel-injection system and vaporiser-cooling device, Professor Robinson stated that he found it impossible to vary the fuel timing so as to cause reversal of the engine by pre-ignitions. This engine, exhibited at the Isle of Ely Agricultural Show in 1893, was awarded the Society's first prize, a silver medal. The test made by Professor Robinson appears to have been in connection with the negotiations then being carried out with Messrs. Richard Hornsby and Sons, Grantham, for the acquisition of the manufacturing rights. In further relation to these negotiations, demonstrations were given to Mr. Robert Edwards, Messrs. Hornsby's chief engineer, on engines in operation at the Bletchley Works. These engines represented both types, *i.e.*, those built in accordance with patent No. 7146 and those built in accordance with patent No. 15994. World manufacturing rights were acquired by Messrs. Richard Hornsby and Sons on June 26, 1891.

Although the engine as handed over to Messrs. Richard Hornsby and Sons proved capable of a good performance on test, much remained to be done before a design was evolved which provided for efficient production and for a standard of reliability in working which would make the engine saleable, particularly abroad. The following are the more important alterations made by Messrs. Hornsby in the design of the original Akroyd engine:—(*a*) In the fuel-injection system the oil pump was improved by reducing the clearances, substituting ball valves for valves of the mitre type, and placing two valves in series on both the suction and delivery sides. The delivery stroke was operated directly, instead of indirectly by a spring. This alteration permitted a small injection nozzle to be used, resulting in better combustion. (*b*) The injector nozzle was water-jacketed to prevent vaporisation of the oil before delivery. (*c*) Governing was effected by a by-pass arrangement instead of by control of the oil pump. Incidentally, this alteration had the advantage of allowing air or vapour to be discharged without passing through the injection nozzle. (*d*) The design of the air and exhaust valves was improved, the former being arranged for mechanical operation. (*e*) Detail improvements were effected in the arrangement of the cylinder and liner. (*f*) The vaporiser was modified in shape in order to obtain a longer life. Fuel oil presented difficulties. Akroyd Stuart had been fortunate in obtaining a fuel oil which proved eminently satisfactory; this was a residue obtained in the manufacture of turpentine substitute, but was not available in sufficient quantity to meet the demand of any considerable number of engines. Suitable petroleum oils were found, however, and an arrangement incorporated in the engine, facilitating adjustment for working with any one of these tested oils.

The engine embodying these modifications was placed on the market as the Hornsby-Akroyd, and was an immediate success. This was a single-cylinder horizontal engine, manufactured in sizes from 1½ h.p. to 16 h.p. In 1896, the water-jacketed vaporiser was fitted, enabling the compression pressure to be raised and the power to be increased. The 16-h.p. engine, as originally manufactured, became a 20-h.p. when fitted with a water-jacketed vaporiser. From this time on, little modification was made to the fundamental design of the Hornsby-Akroyd oil engine, though much attention was devoted to the development of new types and new applications. For example, single-cylinder engines of higher power, up to more than 100 h.p., and multi-cylinder engines of the vertical type, were constructed; applications to road transport were tried out on a traction engine and a lorry; and in 1903 an oil-engined tractor was entered for the

* Paper read before the Diesel Engine Users Association in London, on Thursday, January 11, 1940. Abridged.

military tractor trials at Aldershot. This gained the prize of 1,000*l.* with a bonus of 180*l.* for exceeding, by 18 miles, the stipulated distance of 40 miles to be covered with a load of 25 tons, without replenishment of oil or water supplies. Later this tractor was fitted with chain track in place of its wheels, and the results obtained justify its being regarded as the first step in the development of the "tanks."

One of the authors of this paper served his apprenticeship with Messrs. Richard Hornsby and Sons and spent a considerable part of his time on the Hornsby-Akroyd oil engine. This work commenced in 1897, some five years after the engine had first been put into production. At the time the writer entered the works, two sons and a grandson of Mr. Richard Hornsby, the founder, were associated with the business. In the light of later experience, the writer is of the opinion that at this time the Hornsby works were very efficient. A considerable proportion of the machines were of the latest type; manufacturing methods and organisation reflected good management; while sound practical men were in charge of the foundry, machine and fitting shops. These conditions probably had an important bearing on the successful development of the Hornsby-Akroyd engine, and, within five years of taking over the manufacturing rights, some thirty engines per week were being turned out.

With regard to the demonstration of Akroyd engines given to representatives of Messrs. Richard Hornsby and Sons at the Bletchley Works, and to the test made on one of these engines by Professor Robinson, conflicting statements have been made. These are so interesting that some further reference to them is opportune. Professor Robinson stated that the engine tested by him was working in accordance with patent No. 7146. He also stated that, in the demonstration at Bletchley, engines of both types were running and that, except for small sizes, those working in accordance with patent No. 7146 were preferred. Mr. J. W. Young, in his paper, "Notes on the Practical Development of the Oil Engine,"* remarks that Professor Robinson was in error in stating that the engine which he tested was working in accordance with patent No. 7146. Mr. Young contends that this engine was working in accordance with patent No. 15994, and in support of this he writes as follows: "A reference to Professor Robinson's Cantor Lecture, delivered before the Society of Arts on April 29, 1891, clearly shows that the engine was that covered by patent No. 15994 because it had the contracted neck, oil only being injected into the vaporiser and air drawn in on the cylinder side of the neck." This assumption that the vaporiser with contracted neck was only used on engines working in accordance with patent No. 15994 appears to be based on the patent specifications, and in ignorance of the conditions under which these specifications were prepared.

Since Mr. Young was assistant to Messrs. Hornsby's chief engineer, and responsible for the experimental work in connection with the development of the Hornsby-Akroyd engine, any statement of his cannot lightly be disregarded. Nevertheless, the following considerations indicate the probability that Professor Robinson's record is correct: Akroyd Stuart, working on an engine of the type described in patent No. 7146, developed an improved arrangement of vaporiser. It is difficult to see why he should discard this and revert to the original type. The fact that Professor Robinson had been in close touch with the development work and with the discussions relating to applications for letters patent would ensure attention, on his part, to the system of working of any engine on which he carried out a test. Had there been a departure from the original experimental work it would, without doubt, impress itself on his mind. Further, his statement that he found it impossible to vary the fuel timing so as to cause reversal by pre-ignition would scarcely be made in connection with an engine on which the fuel was injected on the induction stroke.

The importance of the work done by Akroyd Stuart has been obscured by a number of circumstances. To begin with, the indifferent health of the inventor caused him, while still a young man, to settle in Western Australia. Again, the immediate success of the Hornsby-Akroyd engine and the brevity of the period (about one year) during which Akroyd Stuart was in personal contact with Messrs. Richard Hornsby and Sons has tended to create misunderstanding as to the real scope of his contributions to the development of the heavy-oil engine. At the time the Hornsby-Akroyd engine was launched it is doubtful whether much importance would be attached to the difference in fuel timings represented by the two patents. Injection during the induction stroke certainly had advantages for the smaller engines, and in adopting this method Messrs. Hornsby acted wisely. The demand which they had to meet was for engines of the type popularised by the advent of the Crossley gas engine, in which simplicity, reliability and low first cost were of greater importance than high thermal efficiency. The alternative method of injection would have brought no advantage without a considerable increase in the compression pressure, involving great mechanical difficulties.

What Akroyd Stuart accomplished is best understood from a study of his work in its relation to the contemporary state of the art. Eminently the practical type of engineer, almost every move he made is very clearly the result of experiment. He was the first man, so far as we know, who described the cycle of the compression-ignition engine. Although, in the engine which he constructed, a proportion of the heat required to raise the temperature of the air was obtained from the vaporiser, the final ignition temperature, and consequently ignition control, was obtained by compression.

The combustion chamber with contracted neck was certainly among the happiest of all Akroyd Stuart's intuitions, since by these so simple means he was able more or less to stabilise the ignition, and secure good combustion over a wide range of speeds and loads. To-day, with injection arrangements of a perfection undreamt of fifty years ago, the pre-combustion chamber has become a familiar device on small quick-revolution engines. Notwithstanding the advantage which it gives in such important design conditions as those relating to injection pressure, the fuel consumption of small high-compression engines thus fitted is, fuel for fuel, approximately the same—due, doubtless, to turbulence effect and the suppression of late burning—as for engines of comparable size and speed with direct injection combustion chambers. It must also be remembered that, when Akroyd Stuart first adopted the vaporiser with contracted neck, compression pressures were very low, whereas, to-day, compression pressures (and mean effective pressures) are out of all proportion higher.

The water-jacketed vaporiser, enabling the compression to be increased, was an important step towards the final goal of heating the air by compression alone, and made this ultimate development inevitable. In this connection it is interesting to note the parallel exploitation of the Akroyd patents in the United States of America. These were taken up by the De La Vergne Machine Company, and in 1893, Mr. A. H. Goldingham was sent out by Messrs. Hornsby to assist in the development of an engine on the lines of the Hornsby-Akroyd. An engine was produced which, though similar in principle, differed considerably in detail design. This engine was taken up by the oil companies for pipe-line pumping work, for which it proved most successful. Here the use of crude oil was desirable and, to enable the fuel to be utilised, the compression pressure was raised and the proportion of unjacketed vaporiser decreased. This line of development was followed until a compression pressure of 330 lb. per square inch was reached and an engine produced with the characteristics of the modern heavy-oil engine. In the Akroyd engine, working with fuel injection at the end of the compression stroke, ignition control was obtained by compression rather than by timing of the injection. Some years were to elapse before there had evolved an engine which, in general essentials, closely resembled the heavy-oil engine in use to-day. Nevertheless, the inventive steps taken by Akroyd Stuart are such as must cause us to marvel at the prescience which, fifty years ago, enabled him to see so clearly and so far.

In the preparation of this paper the authors have been actuated by a desire to arrive at a clear understanding as to the part played by Herbert Akroyd Stuart in the development of the heavy-oil engine. In studying the information and documents available to them, they have found that a considerable amount of uncertainty and misunderstanding exists in regard to his connection with this development. They do not claim to have set up an incontrovertible position, their hope being that full discussion may correct any inaccuracies and provide additional authentic information. They feel it to be a fitting tribute to the inventor that the fiftieth anniversary of his two most noted patents should be marked by a genuine effort to arrive at a true assessment of their significance in the history of the heavy-oil engine.

* *Trans. Newcomen Soc.*, vol. xvii, page 109 (1937).

ESTIMATING BOILER THERMAL EFFICIENCY.

THERE is no doubt but that a complete test on a steam-raising plant carried out in accordance with the requirements of accepted codes, involves a considerable outlay in the provision of skilled supervision, labour, instruments and other apparatus, and that in many instances a short commercial test will determine all that is needed. A paper entitled "A Simplified Method for Estimating the Thermal Efficiency of Steam Boilers," read by Mr. J. W. Reber, F.Inst.F., of the Woodall-Duckham Companies, before the Institute of Fuel, on Thursday, November 30, discusses such a test which enables the thermal efficiency of steam boilers to be readily estimated with a degree of accuracy sufficient for most purposes, particularly where medium and smaller sizes are concerned. The method should also be useful as a check on the daily operating results of larger units. The paper was originally prepared as an appendix to the gas-fired and waste-heat boiler code which is shortly to be published by the British Standards Institution, permission having been accorded by the Institution for the inclusion in the paper of the section dealing with gaseous-fuel firing, the complete paper covering the application of the short method for solid, liquid and gaseous fuels. The paper is furnished with a large number of graphs, but lack of space prevents its publication in these columns other than in the summarised form in which it here appears.

The simplified method is based on a combination of the heat-temperature (I.T.) diagram evolved by P. Rosin and R. Fehling, and of the combustion charts published in *Technical Data on Fuel*.* The I.T. diagram of combustion illustrates the definite linear relationship of the net calorific value of the fuel to the theoretical air requirements, and to the theoretical volume of combustion products. The combustion charts in *Technical Data on Fuel* show for various fuels of specified properties the relationship between excess air, combustion gas volume and the percentage of CO_2 in the products of combustion and indicate the effect of excess air and waste gas temperature on the stack loss, the latter representing the percentage amount of the net calorific value. The determination of the thermal efficiency of a boiler, based on the Industrial Code of the B.S.I. calls for accurate measurements of the quantities of heat supplied, recovered and lost. The simplified method is based on a heat balance of 100 B.Th.U. net per unit weight, or volume, of fuel supplied to the boiler. For waste-heat boilers, the thermal efficiency is represented by 1 minus the ratio of the percentage heat content of the waste gases, corresponding to the temperatures of the gases leaving and entering the boiler. This ratio is expressed as a percentage of the heat available, and represents, after deduction of radiation and convection losses, the thermal efficiency of waste-heat recovery.

The paper then discusses the new charts constructed by Mr. Reber. As the I.T. diagram equations differ for gases produced by distillation from those resulting from gasification, three combustion charts have been prepared to cover practically all the industrial gaseous fuels used for steam generation, viz., town's or coke-oven gas; producer gas from coal or coke; and blast-furnace gas, the series being completed by charts for bituminous coal and fuel oil, respectively. Three of the combustion charts, viz., those for bituminous coal, fuel oil and blast-furnace gas are reproduced as examples in Figs. 1, 2 and 3, opposite. They are used in connection with the simplified method and have been constructed from certain fundamental equations of the I.T. diagram. A preliminary step is the calculation of the air factor n, that is, the ratio of the actual amount of combustion air A to the theoretical volume A_o. The actual volume V of combustion products per unit volume of gaseous fuel can be written:—

$$V = V_o + \text{excess air}$$

$$n = \frac{A}{A_o}, \text{ or } A = n \times A_o, \text{ excess air} = (n - 1)\,A_o.$$

$$V = V_o + (n - 1)\,A_o.$$

In the above equations, V_o = the theoretical volume of combustion gases in cubic feet at S.T.P. per pound of fuel, solid or liquid, or per cubic foot of gaseous fuel at S.T.P.; A_o = the corresponding volume of combustion air in cubic feet at S.T.P., and H = the net calorific value of the fuel as fired per pound of solid or liquid fuel, or per cubic foot of gaseous fuel at S.T.P. (32 deg. F. and 29·92 in. Hg.).

The charts indicate the volume of combustion products V for air ratios of $n = 1{\cdot}0$ to $n = 3{\cdot}0$, on a calorific value basis of 100 B.Th.U. net per pound or per cubic foot of fuel supplied to the boiler. The value of n must be calculated from the CO_2 content of the products of combustion leaving the boiler, in relation to the theoretical CO_2 content of the fuel under consideration. The theoretical CO_2 content, when not obtainable otherwise, can be assumed to be approximately 18 per cent. for bituminous coals and 15·5 per cent. for fuel oil. The contents for town's gas may be taken as follows:—With a gross calorific value in B.Th.U. per cubic foot, at 30 in. Hg. and 60 deg. F. saturated, of 550, the theoretical CO_2 content, dry, is 11 per cent., rising to 12·0 per cent. for 500 B.Th.U., and to 13·0 per cent. for 450 B.Th.U. The contents of other gases are:—Coke-oven gas, debenzolised, 11 per cent.; producer gas from coal, 19 per cent.; producer gas from coke, 20·5 per cent.; and blast-furnace gas, 24·5 per cent. This last figure has been averaged from 10 English and 14 Continental

* Published by the British National Committee, World Power Conference.

analyses. For bituminous coals, fuel oil and town's or coke-oven gas

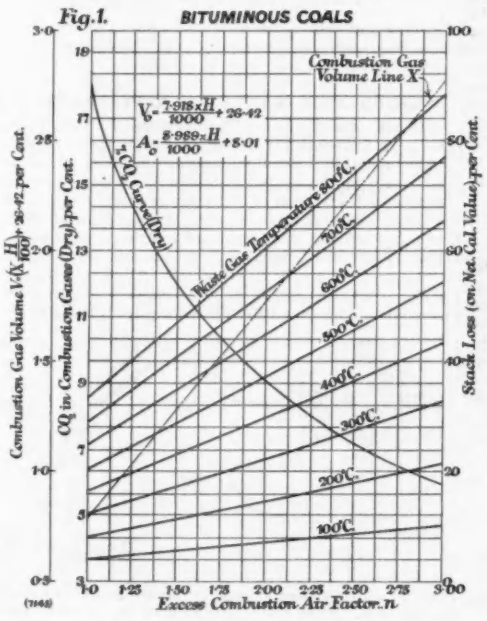
$$n = \frac{\text{Percentage } CO_2\text{, dry, theoretical}}{\text{Percentage } CO_2\text{, dry, in products}}.$$

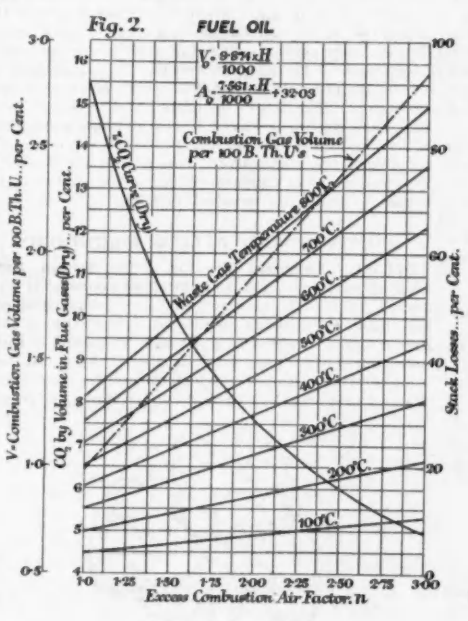
As the dry CO_2 contents of the theoretical combustion gases V_o for bituminous coals and for fuel oil are fairly constant, the charts for these two fuels indicate the corresponding air factor n for a given CO_2 percentage. For producer gas and blast-furnace gas

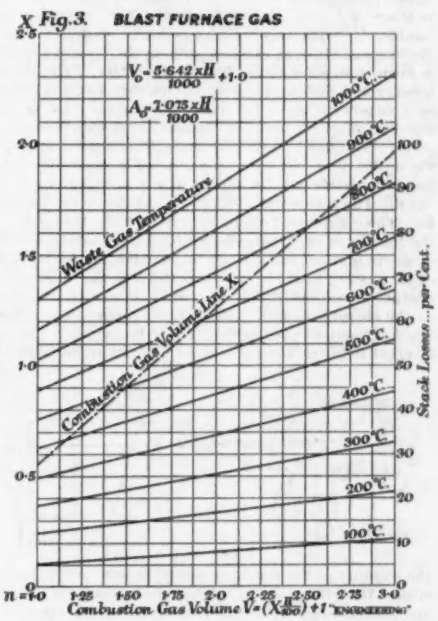
$$n = 1 + \left(\frac{V_o}{A_o} \times \frac{CO_2 \text{ theoretical} - CO_2 \text{ in products}}{CO_2 \text{ in products}}\right)$$

where the CO_2 contents are in percentages, dry basis.

When using the charts, the volume of combustion products V, for any air ratio of n read along the bottom scale, is obtained by the intersection of the appropriate ordinate with the diagonal chain-dotted line and reading on the outermost scale on the left hand of the charts in Figs. 1 and 2, the innermost scale being that relating to the CO_2 content. There is no CO_2 curve on the blast-furnace combustion chart; hence there is only one scale on the left hand in Fig. 3. The diagonal lines shown in full are different temperatures of the waste gases, which temperatures naturally vary, for any one line, with the amount of excess air. It should be noted, however, that no scale of temperatures, as such, is given, the scale at the right hand of the chart







denoting the percentage of the net calorific value of the fuel carried away by the waste gases. Thus, taking, in Fig. 1, an excess combustion air value n of 2·625, and a waste-gas temperature of 500 deg. C., the stack loss is 48 per cent. on the net calorific value of the fuel. Again, in Fig. 3, with a value of $n = 2{\cdot}375$ and a waste-gas temperature of 1,000 deg. C., the total heat supplied is contained in the combustion products.

The charts do not take into consideration any possible sensible heat content of the fuel, either in the form of sensible heat in the case of producer gas, or in the form of preheat from an outside source. In such cases, a correction will have to be made. The percentage heat loss plus the percentage losses by radiation and convection represent the total losses. The thermal efficiency of the boiler under consideration is arrived at by subtracting the total losses from 100. The radiation and convection losses of boilers protected with a good quality of commercial lagging vary from 2 per cent. for larger boilers to 5 per cent. for smaller units. If an economiser or air heater, or both, are included in the boiler plant, the stack loss is based on the temperature of the products leaving the last unit. No further corrections will be necessary except that for the radiation and convection losses already mentioned. The calorific value of town's or coke-oven gas is usually expressed as "gross calorific value at 30 in. Hg and 60 deg. F., saturated." If the net calorific value is not available, this can be ascertained with sufficient accuracy for computing n, by reducing the gross calorific value by 10·5 per cent. To correct the calorific value at 30 in. Hg and 60 deg. F., saturated, to 29·92 in. Hg and 32 deg. F., dry, *i.e.*, S.T.P., a multiplying conversion factor of 1·073 should be used. When it is desired to reduce the gross calorific value at 30 in. Hg and 60 deg. F. directly to the net calorific value at S.T.P. multiplication by 0·95 will give a result in error by only approximately ± 1 per cent. The calorific value of solid and liquid fuels is usually given on the gross calorific value basis, and the only method recognised in this country for converting gross calorific value into net calorific value is that recommended by the Heat Engine Trials Committee of the Institution of Civil Engineers, of which method a short account is given in the paper. Another method possible when the proximate analysis of the fuel is known is also briefly discussed.

The utility of the simplified method is shown by several worked-out examples. The first of these shows the actual results of a test carried out on a small boiler, fired with town's gas, and the application of the simplified method. The recorded particulars of the test are given below :—

Amount of gas used per hour :—	
(*a*) At 30 in. Hg. 60 deg. F., saturated	3,378 cub. ft.
(*b*) At 29·92 Hg. 32 deg. F., dry (S.T.P.)	3,150 cub. ft.
Gross calorific value for (*a*) per cub. ft.	468 B.Th.U.
Net calorific value at S.T.P. per cub. ft.	450 B.Th.U.
Water evaporated per hour	1,062 lb.
Temperature of feed water	60 deg. F.
Steam pressure, per sq. in.	103 lb.
Barometric pressure, per sq. in. ...	14·56 lb.
Absolute pressure, per sq. in....	...117·56 lb.
Heat value of steam above feed temperature, per lb.	1,166 B.Th.U.
Temperature of products leaving boiler	403 deg. F.
CO_2 content, dry, of products leaving boiler	11·3 per cent.
Thermal efficiency on net calorific value of gas	87·47 per cent.

The theoretical CO_2 content of the gas was 12·4 and this figure was used in the simplified method to find n; thus, $n = \frac{12{\cdot}4}{11{\cdot}3} = 1{\cdot}1$. The temperature of the waste gases was 403 deg. F., or 206 deg. C. Using these two figures on the chart given in the paper for town's and coke-oven gas, a stack loss of 8·4 per cent. was found. Assuming that radiation and convection losses amount to 4 per cent., since the boiler was a small one, the thermal efficiency on the net calorific value worked out at $100 - (8{\cdot}4 + 4{\cdot}0) = 87{\cdot}6$ per cent. As calculation from the actual test figures had arrived at a value of 87·47, the difference, *i.e.*, 0·13 per cent., may be disregarded. An error of this amount could, indeed, easily arise from careless observations in the test.

While the correspondence between the two sets of results in the above example is close enough for all practical purposes, the same cannot be said of the next example in the paper, which is concerned with two tests on boilers fired with blast-furnace gas. It may be mentioned, however, that some of the recorded results seem open to criticism. The third example, which applies to waste-heat recovery, is, on the other hand, very informative as the performance of the waste-heat boiler is not always easy to assess. The waste gases in question were from a carbonising plant, which was heated with producer-gas from coke. The CO_2 content of the waste gases was 11 per cent. on the dry basis, and their temperature was 900 deg. C. at the boiler inlet and 250 deg. C. at the outlet. The calorific value of the producer gas was 130 B.Th.U. per cubic foot net at S.T.P. Using the formula given on the appropriate chart reproduced in the paper, the following results were obtained :—

$$V_o = \frac{6{\cdot}451 \times 130}{1{,}000} + 1 = 1{\cdot}839 \text{ cub. ft.}$$

$$A_o = \frac{7{\cdot}785 \times 130}{1{,}000} = 1{\cdot}012 \text{ cub. ft.}$$

$$n = 1 + \left(\frac{1{\cdot}839}{1{\cdot}012} \times \frac{20{\cdot}5 - 11{\cdot}0}{11{\cdot}0}\right) = 2{\cdot}57.$$

With this value of n the volume of the combustion gases calculated from the chart was 3·42 cub. ft., and, also read from the chart, the stack loss at 900 deg. C. was 87 per cent. and that at 250 deg. C. was 23 per cent. The difference, viz., 64 per cent., indicates the heat available, and if 3 per cent. be taken from this for radiation and convection losses, the heat recovered in the form of steam was 61 per cent. The thermal efficiency of the waste-heat boiler was, therefore, $\frac{61 \times 100}{87} = 70$ per cent. With a producer efficiency of 75 per cent. on cold gas and a net calorific value of the coke of 12,500 B.Th.U. per pound, the amount of steam produced per pound of coke charged into the producer was $\frac{12{,}500 \times 0{\cdot}61 \times 0{\cdot}75}{970{\cdot}4} = 5{\cdot}88$ lb. from and at 212 deg. F. Another example applies to a case in which the sensible heat content of the waste gases is augmented by a supply of hot producer-gas and the working out from the chart shows a figure corresponding to actual results obtained in practice, viz., 10·05 lb. of steam, from and at 212 deg. F., produced per pound of coke fed to the producer.

Mr. Reber said he had not been able to prepare comparisons of the results of actual steaming tests, with bituminous coal as fuel, and the simplified method. He pointed out that with bituminous coal, fired either by hand or by a mechanical stoker, there is a further loss due to unburnt combustible matter in the riddlings and fly-ash. This loss is the difference between the heat drop in the boiler, less radiation and convection losses, and the heat actually recovered per unit weight, or volume, supplied to the boiler. The remainder of the paper was concerned with a discussion on the effect of variations in the specific heat of gases and was illustrated by graphs showing the mean specific heat of gases at different temperatures as found by various research scientists. The first graph deals with the specific heat of carbon monoxide, oxygen, nitrogen and air, while the remaining four deal with methane, water-vapour, carbon dioxide and hydrogen, respectively. Mr. Reber pointed out that, although the graphs show considerable differences in mean specific heat, the effect on the stack loss is not very serious. The proposed simplified method is not seriously affected by the particular heat tables employed. In view of this fact, it has been possible to incorporate the principles of the simplified method in an electrical instrument for use in the boiler house. This instrument, made by Messrs. Elliott Brothers (London), Limited, Lewisham, S.E.13, was described and illustrated in ENGINEERING, vol. 143, page 358 (1937), and indicates and records continuously the stack losses as a percentage of the net calorific value of the fuel supplied to the boiler.

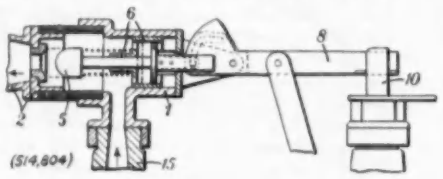
"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.
Where inventions are communicated from abroad, the Names, etc., of the communicators are given in italics.
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.
The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

514,804. Circuit Breaker. The English Electric Company, Limited, of London, and A. R. Blandford, of Stafford. (3 *Figs.*) June 3, 1938.—The breaker is of the high-tension short-break type, in which the moving contact is biased to the closed position and opened by compressed air, which it is usual to exhaust as soon as the arc is extinguished; hitherto, the circuit breaker has then reclosed, the circuit being kept open by an isolating switch in series with the circuit breaker. The invention is a combined circuit breaker and isolating switch in which the breaker remains open so long as the isolating switch is open, and closes just before the latter. The circuit breaker is sealed in an air-tight chamber 1 and is opened by compressed air. The chamber has an inlet boss, a tubular outlet 2 and an insulating sleeve connecting them. The fixed contact consists of a flanged sleeve in the outlet, and the moving contact 5 is mounted on the end of a piston-rod, the piston of which slides in a cylinder 6. The whole assembly is mounted on the insulator 15. The compressed air passes through the insulator and the inlet boss into the cylinder 6. The separation of the contacts is small and the arc is extinguished by the blast of air passing from the chamber through the hollow fixed contact to the outlet 2. The contacts are spring biased to the closed position. After the opening of the circuit-breaker a series isolating switch 8, 10 is opened. The time interval between the opening of the circuit breaker and



the opening of the isolating switch is just long enough to ensure that the circuit is definitely interrupted and the arc extinguished before the isolating switch opens. In order that the air pressure can be cut off without re-closure of the breaker, the cylinder 6 slides in the circuit-breaker chamber and forms a moving abutment for the spring. Secured to the switch blade 8 is a sector having a cam slot in which works a peg in an extension of the cylinder which passes through the closure cap on the end of the circuit-breaker chamber. When the isolating switch is opened, the cam slot withdraws the cylinder and relieves the spring pressure, so that the moving contact remains open when the air pressure is cut off. During the first part of the reclosing movement the cam slot and the peg move the cylinder back to re-apply the spring which closes the circuit breaker; the circuit is completed by the final closure of the isolating switch.—(*Accepted November* 17, 1939.)

MOTOR ROAD VEHICLES.

514,917. Servo-Braking System. Automotive Products Company, Limited, of London, and G. R. G. Gates, of London. (4 *Figs.*) May 18, 1938.—The braking system is of the kind in which the air pressure applied to a piston mechanically connected to the piston of an oil-pressure master cylinder operating the brakes, is controlled by an air-inlet valve actuated by the driver. The object of the invention is to enable the driver to feel the degree of braking applied. An oil-pressure master cylinder 10 is mounted co-axially with an air-pressure cylinder 11, and a piston in the cylinder 11 carries a thrust rod which acts on the piston of the master cylinder. The cylinder 11 is closed by a cover plate, integral with which is a valve block 18, in which are inlet and exhaust valves. The valves are operated by rocker arms 23 and 24 coupled to the brake pedal. The two valves lie side by side and communicate with the cylinder 11 behind the piston. The valve chambers are partly in the valve block 18 itself, and partly in a cover plate bolted to the valve block. The inlet valve (Fig. 2) is operated through a tappet 48 having a limited movement relative to the valve rod 37, a spring being inserted between the rod and the tappet. At its other end, the rod 37 is recessed to receive a spigot on the end of a piston 55 sliding in a cylinder 56. The exhaust valve 58 is spring loaded off its seat and its spindle telescopes into a tappet 66

Fig. 1.

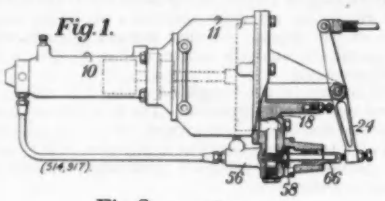
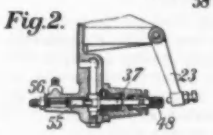


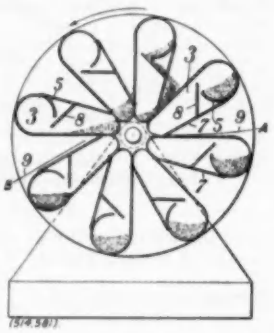
Fig. 2.



sliding in the cover plate. A spring stronger than the loading spring, between it and the valve spindle, permits movement of the rocker arm after the exhaust valve 58 has closed. The cylinder 56 is connected by a pipe to the oil-pressure cylinder 10. With the brakes off, the inlet valve is closed, and the exhaust valve is held open by its loading spring. When the driver depresses the pedal, the initial movement closes the exhaust valve, further movement opening the inlet valve to admit compressed air to the cylinder 11. The compressed air acts on the piston in the air cylinder 11, and thus applies pressure to the piston of the oil-pressure master cylinder 10. The pressure produced in this cylinder applies the brakes and also acts on the piston 55 to oppose the opening of the inlet valve. Thus the driver is able to feel the amount of pressure which is being applied to the brakes.—(*Accepted November* 21, 1939.)

PRINTING AND ALLIED MACHINERY.

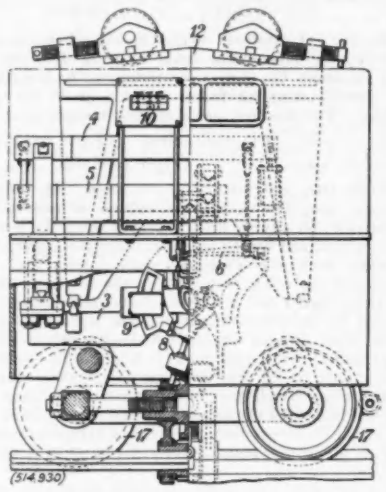
514,581. Embossed Printing. The Selwyn Press, Limited, of London, and D. Gladwell, of London. (1 *Fig.*) June 1, 1938.—The invention is a machine for producing the effect of embossing on printed sheets without using any stamping or deforming action. The drum is rotatable and is partitioned into chambers 3 by a wall bent at one end into a scoop 5 in which the powder is contained. Struts 7 support the scoop and vanes 8 direct the powder



on to the sheet of printed paper 9 as it passes through the apparatus. The sheet enters at A and is rotated with the drum in the direction of the arrow, during which time the powder falls on to it and finally leaves at B. The back of each wall of the chambers forms the support for the sheet. At the exit it falls by gravity from an aperture in the drum. The powder used is a resinous compound which adheres to the print. The sheet is then heated and the printed matter takes on the appearance of being embossed. The process is more economical than those in present use. (*Accepted November* 13, 1939.)

RAILWAYS AND TRAMWAYS.

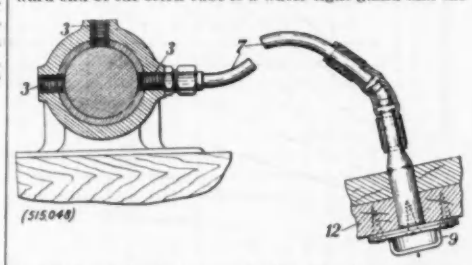
514,930. Locomotive-Weighing Apparatus. W. and T. Avery, Limited, of Birmingham, and A. Binns, of Birmingham. (2 *Figs.*) June 11, 1938.—The figure shows one unit of a battery of weighing units, one for each locomotive wheel. A lever system 3, 4, 5 and 6 is mounted in an inverted box frame. This lever system is coupled through the lever 6 to a weight 8 and to the load, the weight, in turn, being associated with a transparent sector 9 which carries the weight markings. These are projected by a light on to a screen 10. A headstock 12 carries a pair of sliding blocks fitted with rollers to support the flange of a wheel. The blocks are adjusted by screws, and the load on them is transmitted to the main lever 3 of the lever system. The axles of the wheels 17 are journalled in links which are pivoted at their upper ends on the box frame. The links can be rocked slightly about their pivots by a horizontal screw shaft to raise or lower the box frame and lever system, and the locomotive wheel is lifted from the track for weighing by raising this frame. In order to lift or lower the separate



weighing units associated with each wheel, the horizontal screw shafts are coupled together and to a common power source.—(*Accepted November* 21, 1939.)

SHIPS AND NAUTICAL APPLIANCES.

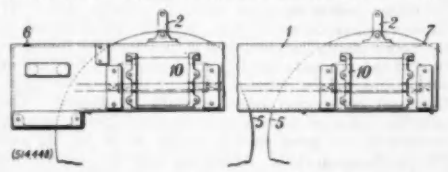
515,048. Cooling Stern-Tube Bearings. H. Scott-Paine and G. H. S. Thomas, of Hythe. (2 *Figs.*) April 22, 1938.—The invention is a device for producing a flow of cooling water through the stern-tube bearings of relatively small, high-speed boats, such as 70-ft. motor boats. A number of holes 3 are drilled through an orthodox type of stern-tube and bearing at the forward and upper end of the tube. Each hole is provided with an adaptor to which a copper flow-pipe 7 is connected. Each flow-pipe is joined at its other end to an outlet scoop 9. At the forward end of the stern-tube is a water-tight gland and the



orifices 3 are situated as near to the aft end of this gland as possible. Thus the circulation of water cools both the white-metal bearing and the gland, and also leakage through the gland is reduced, as the water is sucked away from the bearing at a point below the gland. The fitting 9 is screwed to the bottom 12 of the boat, so as to be submerged when the boat is in the water. The scoop is directed away from the flow of water caused by the motion of the boat through the water. The orifices of the fittings 9 are designed to extract a substantial flow of sea-water from the stern-tube at a minimum boat speed of 8 knots, so that at higher speeds of revolution of the shaft a greater volume of water is circulated.—(*Accepted November* 24, 1939.)

MISCELLANEOUS.

514,448. Mechanical-Stoker Mounting. J. and J. Neil (Temple), Limited, of Glasgow, J. M. Neil and J. Welsh, of Glasgow. (5 *Figs.*) May 6, 1938.—The invention is a mounting panel for the stokers of Lancashire boilers. A panel unit 1 carries the stoker units and is suspended from the boiler by links 2 which are adjustable in length



to allow correct setting of the panel unit relative to the furnace openings in the front plate 5. The panel unit is of box form and has connections 6, 7 for the circulation of cooling water. The openings in the unit which register with the furnace openings have seats 10 for the components of the stoker units. This method of mounting the stokers obviates the difficulties due to expansion and contraction of the boilers. (*Accepted November* 8, 1939